EVALUATION OF THE MINERAL STATUS OF CATTLE IN SPECIFIC REGIONS IN GUATEMALA

BY

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A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1984

ACKNOWLEDGMENTS

The author wishes to express his sincere gratitude and appreciation to all those who collaborated in the preparation of this dissertation.

Special appreciation is due to his advisor and chairman of his supervisory committee, Dr. Lee R. McDowell, for his guidance. Acknowledgments are also due to Dr. Joseph H. Conrad, Dr. Rachel Shireman, Dr. Frank G. Martin and Dr. Clarence B. Ammerman for their valuable advice as members of the supervisory committee. Recognition is due to Dr. Frank G. Martin for his assistance in statistical analysis.

The author is especially grateful to his parents, Dr. and Mrs. Carlos Tejada, and to Cervecería Centroamericana S.A. for their encouragement and financial support during this academic endeavor.

Special appreciation is due to Dr. Francisco Rodas, who assisted in organizing and helping in the sample collection in order to make this work possible. The author wishes to give recognition to Dr. Ricardo Bressani of INCAP for allowing the use of laboratory facilities in order to prepare the samples for shipment to the U.S.A. The writer extends thanks and deep appreciation to Mrs. Nancy Wilkinson and Mrs. Pamela H. Miles for their assistance in laboratory work.

The author extends his gratitude to the ranch owners in Guatemala, Mr. Jesus Aguirre Sucs., Mr. Carlos A. Asturias, Mr. Rafael Asturias, BANDEGUA, Mrs. Alicia H. de Bressani, Mr. Ramón Campollo, Mr. Enrique Fernandez, Industrias Agrícolas Centroamericanas S.A., Mrs. Angelina M. de Molina and Mr. Gerardo Perez, who graciously offered their land and animals and, through their personnel, assisted in the collection of samples.

Thanks are also extended to Ms. Sarah McKee for the preparation of the manuscript.

Finally, the author wishes to give special recognition to his wife, Kimberly Ann, and his daughter, Analee, for their patience and understanding during the execution of this task.

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Abstract of Dissertation Presented to the Graduate Council
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

EVALUATION OF THE MINERAL STATUS OF CATTLE IN SPECIFIC REGIONS IN GUATEMALA

By

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April 1984

Chairman: Dr. L. R. McDowell
Major Department: Animal Science

A study was conducted in three livestock-producing regions of Guatemala to determine the mineral status of grazing cattle by detecting mineral deficiencies or toxicities. Soil, forage and animal tissue samples (blood, bone, liver) were collected from different farms within three regions (Northeast, Central and Southwest) during the rainy and dry seasons.

The minerals found to be most likely deficient in soil in both seasons were phosphorus, copper, potassium, manganese, iron and zinc.

In both seasons, minerals most likely to be deficient in forages were sodium, magnesium, copper, phosphorus, selenium and zinc. Based on analyses, mineral and crude protein concentrations among forage species tended to differ. The results showed a high incidence of low correlation coefficients between soil and forage minerals.

During both seasons, minerals most likely to be deficient in the Northeast region in blood plasma were copper and phosphrous. Central and Southwest regions were likely to be deficient in plasma phosphorus and selenium. Plasma phosphorus was higher ($P < 0.10$) for both seasons in growing steers than in lactating cows.

Bone parameters did not vary ($P < 0.05$) among regions during either season, with the exception of specific gravity in the rainy season.

Liver minerals most likely to be deficient in the rainy season for each of the regions were copper in the Northeast region and copper, manganese and selenium in the Central and Southwest regions. High incidence of deficiency during the dry season was found for liver copper in the Northeast region.

The minerals limiting cattle production in Guatemala during the rainy season were calcium, sodium, phosphorus, copper and zinc in the Northeast region; in addition to the above minerals, manganese and selenium in the Central region; and calcium, magnesium, sodium, phosphorus, manganese and selenium in the Southwest region. In the dry season, the same minerals were limiting in each of the regions, in addition to magnesium in the Central region. Some degree of selenium toxicity was found in the Northeast region.

CHAPTER I
INTRODUCTION

Guatemala occupies 108,889 square kilometers and is the northernmost Central American country. The central highlands and mountain areas are bordered by the narrow Pacific coast, the lowlands and fertile valleys located on the Caribbean. There are two seasons, the rainy season which extends from May to October, and a relatively dry season from November to April. The annual precipitation is extremely varied, depending on the region, ranging from 1,000 to 4,000 mm.

More than 50% of the cattle are raised in the five departments of the south coast. Cattle production in the north coast has expanded as new roads have opened up new pasture lands. Feed is in short supply during the dry season and the extremely heavy rainfall from May to October makes it difficult to prepare and store roughages during the wet season for dry season feeding. As a result, cattle frequently lose weight during the dry season and the size of the annual calf crop is reduced. The problem of providing adequate feed for cattle throughout the dry season has been cited as the most critical factor facing the cattle industry. Recently, solutions to the problem of dry season feeding have been attempted with the introduction of improved forages (including legumes), the utilization of crop residues and by the introduction of new systems in preserving forages.

As is known, in many areas of the world and particularly in the tropics, undernutrition is commonly accepted as the most limiting factor to herbivore livestock production. If new technology and intensification methods are applied to the livestock production of this zone, there could be an increase in the nutritional problems of the system. Therefore, supplemental feeding of adequate minerals, which are frequently deficient in tropical pastures and forages, can partially improve this undernutrition problem. One of the largest cost-to-benefit ratios in the system can be obtained with this method.

The objectives of this research were to provide the basis for an efficient and low cost mineral supplementation program throughout Guatemala by:

1. Establishing if specific mineral deficiencies or toxicities exist in the country.
2. Evaluating and comparing the mineral status of soil, forages, and beef cattle tissues at different physiological states.
3. Determining the season, region and/or farms in which mineral deficiencies occur and, therefore, establishing the conditions in which animals are likely to respond to mineral supplementation.

CHAPTER II
LITERATURE REVIEW

Characterization of the Cattle Industry in Guatemala

Guatemala is a Central American country located south of the Yucatan Peninsula of Mexico. It is bounded on the north and west by Mexico, on the east by Honduras and El Salvador, and on the south by the Pacific Ocean (Fletcher et al., 1970; Instituto Geográfico Nacional, 1972).

Guatemala's capitol, Guatemala City, lies at latitude 14°33'30" and longitude 90°43'50" and the altitude is 1,500 m above sea level (Instituto Panamericano de Geografía e Historia, 1978).

A wide geographical diversity exists within Guatemala's total area of 108,889 square kilometers. This land includes high mountain ranges, coastal plains, tropical jungle, volcanic areas, and a dry, almost desert zone. Consequently, climate varies considerably from one area to another due to differences in altitude, location of the mountains, and direction of winds (Fletcher et al., 1970; Early, 1982).

The variety of geographical areas, combined with a wide range of climates and soil types, are elements which determine the structure of cattle production in the different regions of the country. These elements also influence the quality and quantity of resources available to the cattle industry.

In general, Guatemala's cattle production is found in two climatic regions: the coastal lowlands with high temperatures all year, ranging from 20 to 33°C, and the highlands which are relatively cool, with temperatures averaging around 17 to 22°C most of the year, with occasional low temperatures in some areas (Fletcher et al., 1970).

Holdridge et al. (1950), based on average annual rainfall, temperature and altitude, delineated Guatemala's vegetative areas into four zones: tropical, subtropical, low mountainous and mountainous. The tropical and subtropical zones offer the best ecological conditions for cattle production (Departamento de Investigaciones Agropecuarias e Industriales del Banco de Guatemala, 1965). Table 1 provides a description of these two zones.

The differences in ecological characteristics, demographic concentration, market proximity, hydrological resources and communication systems have developed distinct cattle regions in the country, and accordingly, different cattle production purposes and procedures. In this way, the cattle industry is distributed among four regions as is shown in Figure 1 (Departamento de Investigaciones Agropecuaries e Industriales del Banco de Guatemala, 1965).

The southern region covers the lower altitude sections of the southern departments. This is the most important cattle region in the country; it includes about 50% of the total cattle population. The region forms a belt approximately 400 km long and 60 km wide. It is known in the soil classification by Simmons et al. (1959) as the "The Pacific Declive". Due to altitude and rainfall, it is classified within the "tropical humid forest" and "tropical dry forest" ecological zones. The topography of the region is relatively flat; approximately 80% of the land is arable. Altitudes of the southern region vary between 0 and 900 m above sea level, with temperatures ranging from 18 to 32°C. The mean annual rainfall is approximately 1,500 to 3,000 mm per year distributed from May to November

TABLE 1. GUATEMALA'S VEGETATIVE AREAS FAVORABLE FOR BEEF CATTLE PRODUCTION

Vegetative Zone[a]	(km²)	Mean annual temperature (°C)	Mean annual rainfall (mm)	Location
Tropical Zone	62,000	24°C		Coastal Lowland
Very dry	1,600		500-1,000	"Boca Costa"
Dry	21,200		1,000-2,000	Northern Petén Lowland Southern Coast
Humid	39,200		2,000-4,000	Southern Coast
Subtropical Zone	25,800	18-24°C		
Dry	12,700		500-1,000	Western zone
Humid	4,900		1,000-2,000	Western zone

[a] Holdrige et al. (1950, cited by Guatemala National Bank Publication, 1965).

(Departamento de Investigaciones Agropecuarias e Industriales del Banco de Guatemala, 1965).

The Central Region mainly includes the highlands, where there is less arable land and temperatures are lower. Only about 7% of the total cattle population occupies the Central Region. Purebred and dairy operations are predominant, since the ecological conditions are favorable for this type of cattle production.

The Northern Region includes the north coastal departments and the "Boca Costa", where the potential for extensive beef cattle production seems to be immense. Several development projects have evolved in order to enable maximal utilization of the region.

The area with one of the highest cattle populations, Izabal, has a rain forest climate with high average temperatures (Tergas, 1965). Average rainfall is approximately 2,000 to 3,000 mm, conditions which allow both cow-calf and backgrounding operations. Between 10 and 20% of Guatemala's cattle population is located in this zone. The low cattle population in the area is due to numerous diseases and the lack of communication systems, both of which influence the low quality of cattle performance. However, the high monetary value and the cost of labor in the Southern Region, as well as its diversification to high cash crops, has developed new cattle operations in the northern region (Departamento de Investigaciones Agropecuarias e Industriales del Banco de Guatemala, 1965).

Mineral Status of Soil

Soil Origin and Characterization in the Tropics

Many concepts of the relationship of rock or parent material to derived soils have changed substantially since Morton's pioneering observations (Reid and Horvath, 1980). However, it is still recognized that the parent rock from which a soil is formed can influence the quantity of minerals available to the plant as well as the availability of applied nutrients (Reid and Horvath, 1980). Krauskopt (1972) suggested that soils should have, on the average, a similar composition to that of the earth's crust; however, the raw material from which soils are derived is so variable in composition, and the soil-forming processes are so different from one climatic regime to another, that the mean soil composition can have little significance. Hemphill (1977) found little relationship between soil chemistry and mineral composition of native vegetation and farm crops. Therefore, the mineral intake by livestock depends more on the type of plant and the intake level than on the parent rock from which the soil originated (Hemphill, 1977; Reid and Horvath, 1980).

Allaway (1968) indicated that content of soil minerals depends not only on parent material but on much more complex pedogenic factors which include laterization , calcification, podzolization and salination. In the soil profile, translocation occurs by processes of leaching, surface erosion and evaporation, with transport to the soil surface resulting in a redistribution to the upper horizons of the soil (Beeson and Matrone, 1976). In this way, Lindsay (1972) comments, a true equilibrium in soils is probably never attained and solid phases are difficult to characterize.

The chemical characteristics of oxisols represent a special problem in tropical soils (Brady, 1974). Their most important diagnostic feature is the presence of a horizon generally high in clay-size particles dominated by hydrous oxides of iron and aluminum. That, coupled with low cation exchange capacities, results in the removal of not only macronutrients but micronutrients as well (Kamprath, 1973a; Brady, 1974; Sanchez and Isbell, 1979; Reid and Horvath, 1980).

Soil Acidity and the Effect of Lime

Sanchez and Isbell (1979) indicated that much of the tropical area of Latin America is dominated by highly acid soils with pH levels ranging from 3.8 to 5.5. The effects of soil acidity on the plant are summarized by Bould (1965) as follows: physiologically impaired absorption of calcium, phosphorus and magnesium; increased solubility, to a toxic degree, of aluminum, manganese and, possibly, iron and heavy metals; reduced availability of phosphorus, partially by interaction with aluminum or iron; reduced availability of molybdenum.

Mott and Popenoe (1977) indicated that applications of lime to the soils, raising the pH to a level between 5 and 6, may neutralize the exchangeable aluminum sufficiently to reduce fixation of phosphorus and increase the rate of decomposition of organic matter. Blue (1979) reported that the massive quantities of calcium and magnesium added to the soil in lime will remove the aluminum from the exchange sites and reduce the amount of positive charge per atom of aluminum, thus shifting the equilibrium so that more $Al(OH)^{2+}$ is present, while there is less Al^{3+} which interferes with the absorption of calcium and phosphorus by plants.

Popenoe (1960) indicated that parent material, topography and climate have a very significant effect on the pH of the immature soils in the Polochic Valley in the Northern Region of Guatemala. The soils on the steep slopes found at Matanzas, in the driest part of the Polochic Valley where limestone is very near the surface, have a pH close to neutral. In the same valley, at Los Alpes, soils receiving more rainfall and on less steep slopes were found to be the most acid (Popenoe, 1960). Tergas (1965) conducted a study in Izabal (Northern Region of Guatemala) and indicated that in the Icacal zone, the pH ranged from 4.8 to 5.0 while in the other sites, pH was found to be close to neutral.

Soil Calcium, Phosphorus, Potassium and Magnesium

Soil calcium deficiencies can occur in humid regions where rainfall exceeds evapotranspiration for most of the year, bases have been depleted and soil acidity has developed (Kamprath and Foy, 1971; Thompson and Troeh, 1978). The exchangeable calcium in a soil has an important relationship with soil pH and with the availability of several nutrient elements. However, an excess of calcium results when calcium carbonate precipitates, resulting in low solubility of phosphorus, iron, boron, manganese and zinc (Thompson and Troeh, 1978).

Breland (1976) indicated that by using the double acid extraction method for analysis of Florida soils, the levels in the soil solution that are considered low, medium and high are determined, as presented in table 2. Calcium levels from 0 to 71 ppm in the soil solution are considered as low, 72 to 140 ppm as medium, and 141 ppm or more as high.

Phosphorus deficiencies in soils and pastures have been observed in "almost every corner of the globe" (Theiler and Green, 1932, quoted by Reid and Horvath, 1980). With the possible exception of nitrogen, no other element has been as critical in the growth of plants in the field as has phosphorus (Brady, 1974). Phosphorus loss from soils of the tropics is determined primarily by cropping intensity, erosion and leaching (Olson and Engelstad, 1972). Furthermore, Beeson and Matrone (1976) reported that a low availability of soil phosphorus may be due more to soil reactions such as high acidity or alkalinity, resulting in the formation of insoluble iron or aluminum phosphates or basic phosphates, than to total concentration of phosphorus in the soil.

Both inorganic and organic forms of phosphorus occur in soil, and both are important to plants as sources of this element. The organic

TABLE 2. SOIL EXTRACTABLE MINERAL VALUES AND APPROXIMATE INTERPRETATION BY DIFFERENT RESEARCHERS

Element	Soil extractable mineral			Extracting reagent	Soil type or pH	Reference
	Low	Medium	High			
Calcium	0-71	72-140	>141	.05N HCl + .025N H_2SO_4		Breland, 1976
Magnesium	0-9.1	9.2-21.1	>22.2	.05N HCl + .025N H_2SO_4		Breland, 1976
	0-30	30-50	>60	.05N HCl + .025N H_2SO_4		Rhue and Kidder, 1983
Phosphorus	0-5	6-13	14-25	.05N HCl + .025N H_2SO_4		Breland, 1976
	0-10	11-30	>30	.05N HCl + .025N H_2SO_4		Bahia, 1978
	9-17	17-30	30-60	.05N HCl + .025N H_2SO_4	Sandy	Rhue and Kidder, 1983
	9-17	17-35	35-70	.05N HCl + .025N H_2SO_4	Organic-mineral	Rhue and Kidder, 1983
Potassium	0-30	31-79	80-105	.05N HCl + .025N H_2SO_4		Breland, 1976
	0-60	61-120	>121	.05N HCl + .025N H_2SO_4		Bahia, 1978
	19-37	37-62	62-124	.05N HCl + .025N H_2SO_4	Mineral	Rhue and Kidder, 1983
	31-62	62-124	124-248	.05N HCl + .025N H_2SO_4	Organic-mineral	Rhue and Kidder, 1983
Sulfur	<10	>10		NaH_2PO_4 in HO Ac		Cooper, 1968
Boron	<0.4			Hot H_2O		Gammon, 1976
Cobalt	<0.1	0.1-1.41		CH_3COOH		Kubota, 1964
Copper	<0.2	>0.2		.005M DTPA, .005M $CaCl_2$, .1M Tea		Viets and Lindsay, 1973
	<.1-.3			.05N HCl + .025N H_2SO_4	pH 5.5-6.0	Rhue and Kidder, 1983
	<.3-.5			.05N HCl + .025N H_2SO_4	pH 6.0-6.5	Rhue and Kidder, 1983
	<.5			.05N HCl + .025N H_2SO_4	pH 6.5-7.0	Rhue and Kidder, 1983

TABLE 2 - continued.

Element	Soil extractable mineral			Extracting reagent	Soil type or pH	Reference
	Low	Medium	High			
Iron	<2.5	>4.5		.005M DTPA, .005M $CaCl_2$, .1M Tea		Viets and Lindsay, 1973
Manganese	<1	>1		.005M DTPA, .005M $CaCL_2$, .1M Tea		Viets and Lindsay, 1983
	<3-5			.05N HCl + .025N H_2SO_4	pH 5.5-6.0	Rhue and Kidder, 1983
	<5-7			.05N HCl + .025N H_2SO_4	pH 6.0-6.5	Rhue and Kidder, 1983
	<7-9			.05N HCl + .025N H_2SO_4	pH 6.5-7.0	Rhue and Kidder, 1983
Molybdenum	<.1			1N HCl or 1N NH_4OH		Gammon, 1976
Zinc	<.5	.5-1	>1	.005M DTPA, .005M $CaCl_2$, .1M Tea		Viets and Lindsay, 1973
	<1			.1N HCl		Gammon, 1976
	<.5			.05N HCl + .025N H_2SO_4	pH 5.5-6.0	Rhue and Kidder, 1983
	<.5-1			.05N HCl + .025N H_2SO_4	pH 6.0-6.5	Rhue and Kidder, 1983
	<1-3			.05N HCl + .025N H_2SO_4	pH 6.5-7.0	Rhue and Kidder, 1983

component, constituting 20 to 80% of the total, is inert before mineralization; after this, it contributes significantly to the phosphorus nutrition of plants (Brady, 1974; Dalal, 1977; Reid and Horvath, 1980). Most inorganic phosphorus compounds in soils fall into those containing calcium and those containing iron and aluminum (Brady, 1974). Therefore, the availability of inorganic phosphorus is largely determined by the following: soil pH, soluble iron, aluminum and manganese; presence of iron-, aluminum- and manganese-containing minerals; available calcium; amount and decomposition of organic matter and clay content; soil moisture; temperature; and aeration (Brady, 1974; Munson, 1978; Reid and Horvath, 1980). Kamprath (1973b) indicated that adjusting the pH of acid aluminous latosols, commonly found in the tropics, to a 7 rapidly decreases the uptake of phosphorus present in the fertilizer, while the formation of $CaPO_4$ was the main cause for the decreased phosphorus intake.

Larsen (1967) comments that the total phosphorus content of virgin soils varies widely; the average content of phosphorus in humid soils is 490 ppm. Analysis of soils, using the double acid extraction method, indicated that a phosphorus content of 0 to 5 ppm in the soil solution is very low; 6 to 13 ppm is considered low; 14 to 25 ppm is medium; and a content of 25 to 50 ppm is very high in this macroelement (Breland, 1976; Bahia, 1978). This extractant was formerly referred to as the double-acid extractant. However, it is now called the Mehlich I extractant by the Soil Science Society of America (Rhue and Kidder, 1983), and its interpretation for different analysis of elements in Florida soils is presented in table 2.

In contrast to the situation regarding phosphorus, most soils, except those of a sandy texture, are comparatively high in total potassium. Most of this element is fixed in the primary mineral or is found in forms that are only moderately available to plants (Rhue and Street, 1980). The various forms of potassium in soils can be classified on the basis of availability; these can be grouped as unavailable, readily available and slowly available. By far the greatest part, approximately 90 to 98%, of all soil potassium in a mineral soil is relatively unavailable (Blue, 1974; Tisdale and Nelson, 1975; Rhue and Street, 1980; Schaff and Skogley, 1982). The major reserve of this form of potassium is found in feldspar, muscovite and biotite. The readily available potassium constitutes only about 2% of the total amount of this element in an average mineral soil. It exists in soils as potassium in the soil solution and as exchangeable potassium adsorbed on the soil colloidal surfaces.

Beringer (1978) assumed that tropical and subtropical soils are not totally deficient in potassium due to low yields of crops, and there is little removal of potassium during shifting cultivation. Most potassium losses from the soil occur through crop removal and leaching, which is usually quite high in sandy and low exchange capacity soils (Rhue and Street, 1980). Therefore, liming very acid soils up to pH 5.5 will have a small beneficial effect on potassium retention because of an increase in the effective cation exchange capacity of acid soils as the pH increases (Rhue and Street, 1980; Schaff and Skogley, 1982). Similar information is provided by Popenoe (1960) for the humid tropical climate of the Polochic Valley in Guatemala where he found that clearing and burning of plant material would deposit large amounts of exchangeable potassium in the topsoil. He also stated that the breakdown of clay materials by active weathering probably accounts for some of the high potassium levels found in the zone.

Bahia (1978), using the double-acid extraction method of soil analysis, indicated the following values as criteria for available potassium in soils: 0 to 60 ppm, low; 61 to 120 ppm, average; and greater than 120 ppm, high.

Metson (1974), in a review of factors affecting the availability of soil magnesium, stated that the main sources of weatherable magnesium in basic igneous rocks and the soils formed from them are the ferromagnesian minerals (amphiboles, pyroxenes, olivines) and the secondary carbonate minerals dolomite and magnesite. The amount of magnesium in the soil is strongly influenced by the process of weathering. Only a small proportion of the total magnesium present in the soil is available to the plant. Metson (1974) stated that the preferred level of exchangeable magnesium is frequently placed at about 10% of cation exchange capacity and also concluded that the exchangeable magnesium, in part, determines availability of magnesium to the plant. On the other hand, Christenson and Doll (1978) reported that the total magnesium uptake by plants was not related to the total magnesium levels, clay percentage or exchangeable magnesium levels in the soil. However, Baker (1972) emphasized that plant uptake will also be affected by adsorption energy of the solid phase of magnesium, by mineral composition and by interactions of magnesium with other cations which may be expressed as ratios (Mg/K, Mg/Ca, Mg/Al).

Sanchez (1976) indicated that many acid soils in the tropics are deficient in magnesium without having aluminum toxicity problems; therefore, these soils respond directly to magnesium fertilization. On the other hand, reducing aluminum toxicity in the subsoil is a most difficult management problem in many areas of the tropics. The possibility of downward movement of calcium and magnesium is one alternative; this can be achieved by application of lime in combination with ammonium sulfate. Therefore, a movement occurs in the form of exchangeable calcium and magnesium as well as calcium and magnesium sulfate.

Breland (1976) reported that for Florida soils analyzed using the double-acid extraction method, values from 0 to 9.1 ppm are low, 9.2 to 21.1 ppm magnesium are medium, and more than 21.2 ppm are high.

Recently, Rhue and Kidder (1983) indicated that for agronomic and vegetable crops grown on acid soil in Florida, the amount of Mehlich I extractable magnesium is interpreted as follows: less than 30 ppm, low; from 30 to 60 ppm, medium; and more than 60 ppm, high (table 2).

Table 3 presents a summary of the recommendations for fertilization of field and forage crops based on the soil test results, using the Mehlich I method of extraction for calcium, phosphorus, potassium and magnesium.

Soil Copper, Molybdenum, Iron, Manganese and Zinc

There are two general sources of readily available nutrients in the soil: those nutrients adsorbed by the colloids and salts in the soil solution. In both cases, the essential elements are present as ions. The positively charged ions (cations) are mostly adsorbed by colloids, whereas the negatively charged ions (anions) and a small fraction of the cations are found in the soil solution (Brady, 1974).

In general, potassium, calcium, magnesium, zinc, boron and chlorine occur in the soil solution in only one ionic form. Since iron, manganese and copper are present in different ionic forms, the oxidation-reduction condition of the soil plays an important role. If the soil is well aerated, the ions of higher valence tend to predominate, but if drainage is

TABLE 3. SUMMARY OF RECOMMENDATIONS FOR FERTILIZER APPLICATION OF MACRONUTRIENTS

Macronutrient	Recommended fertilizer application on basis of soil test results (Mehlich I extraction method)			Soil type	Reference
	Low	Medium	High		
Calcium (CaO - kg/ha)	Soil-test results, in ppm				
Forage crops (Florida)	--	--	--	All soils	Breland, 1976 Whitty et al., 1977
All forages	Depends on pH, when liming is needed				Rhue and Kidder, 1983
Phosphorus (P_2O_5 - kg/ha)	Soil test results, kg P_2O_5/ha				
Forage crops (Florida)	<90	91-147	>148	Sandy soils	
New plantings	90	45	23		
Established stands-grazing	90	45	23		
Legume-grass pasture	112	67	34		Whitty et al., 1977
Potassium (K_2O - kg/ha)	Soil test results, kg K_2O/ha				
Forage crops (Florida)	<101	102-168	>169	Mineral soils	
New plantings	90	45	23		
Established stand-grazing	90	45	23		
Legume-grass pasture	180	135	90		Whitty et al., 1977
Magnesium (MgO - kg/ha)	Soil test results, in ppm				
Forage crops (Florida)	<30	30-60	>60	All soils	
All forages	Depends on pH, when liming is needed				Rhue and Kidder, 1983

poor, reduction may occur and the lower valence forms will be present (Brady, 1974; Sanchez, 1976; Reid and Horvath, 1980).

Available copper is present in soils as cupric ions and some cuprous ions in primary minerals, as adsorbed chelated ions on clay particles and as ions in true solution. When amounts of copper exceed the adsorption capacity and acid and oxidizing conditions are given, then abundant copper may be present in the soil solution (Krauskopt, 1972; Baker, 1974; Jarvis, 1981). Furthermore, McLaren et al. (1983), in a study of the ability of copper adsorbed by soil components to desorb back into solution, proposed that the amounts of copper which can be readily desorbed from soil components are very small. It is clear that desorption or lack of desorption is very important in affecting plant availability of indigenous or added soil copper. Sanders (1982) indicated that as pH increases, the quantity of copper adsorbed increases and the proportion of copper in solution as cupric ion decreases.

Factors affecting the level of copper in soils include parent material, organic matter, clay concentration and soil pH. Therefore, Reid and Horvath (1980) indicated that agricultural soils contain, on the average, about 20 ppm of copper, with a range of 2 to 50 ppm. Similar values are given by Horwitz and Dantas (1973) for copper in the surface horizon, since copper has a tendency to concentrate in this horizon, bound to the soil organic matter and clay minerals.

In general, available molybdenum is high in alkaline soils rich in organic matter and in soils derived from volcanic materials, whereas molybdenum deficiencies are associated with soil pH levels below 5.5 (Mortvedt et al., 1972; Davis, 1974). Beeson and Matrone (1976) observed that soils often associated with copper-molybdenum problems in grazing ruminants are the peats, muck soils and other poorly drained soils with high organic matter content. This is thought to be due to the strong binding of copper to organic complexes. Aubert and Pinta (1977) indicated that the solubility or availability of copper tends to decrease as the pH of the soil increases, although the effects of pH on copper are not as marked as the effect on molybdenum uptake.

A number of studies have been undertaken to determine the variability of physical, chemical and morphological properties within and between soil series and to assess the optimum sample size for given levels of precision (Khan and Northcliff, 1982). Furthermore, in their study of variability of selected soil micronutrients in a single soil series, they indicated that iron and manganese showed the greatest spatial variability and, hence, require the largest sample size.

Lindsay (1972) indicated that the solubility of iron in soils is largely controlled by the solubility of hydrous iron (III) oxides and that the total inorganic iron in solution varies with pH.

Manganese occurs in the soil in many different chemical forms, most of which are not readily available to growing plants. Manganese as Mn^{2+} held on the soil exchange sites and water-soluble manganese are the forms mostly utilized by plants (Street and Rhue, 1980a). The oxidation and reduction status, and soil pH are the two most important factors controlling the solubility and availability of manganese. Under reduction conditions (wet soils), manganese is solubilized while under oxidizing conditions (dry soils), it is precipitated or immobilized. The soil pH at which manganese is most available is between pH 5.0 and 6.5. Therefore, in soils, the concentration of manganese shows a wide range, from less than 20 up to 6,000 ppm (Lindsay, 1972; Street and Rhue, 1980a).

Sanders (1983) reported the effect of pH on the total free ionic concentration of manganese in soil solutions and concluded that manganese concentration in the soil solutions decreased as the pH increased. At the same time, the solubility of manganese in soils is largely controlled by the solubility of their oxides. Norrish (1975) found that the availability of cobalt was regulated by the manganese oxides which contained high concentrations of iron, cobalt, nickel and zinc.

Determination of the activities of free ions in trace metals in the soil solution is of great importance in the study of the uptake of these metals by plants, since the free ion enters into equilibrium among different forms of the metals in solution (Sanders, 1983). Zinc appears in the soil depending on the pH; at pH below 7.7, it is present mainly as Zn^{+2} and above this value, $Zn(OH)_2$ is more frequently found. The solubility of Zn^{+2} is highly dependent on pH, and it decreases as pH increases (Lindsay, 1972). Similar results were reported by Sanders (1983), who indicated that extractable zinc concentration in the soil solution decreased as the pH increased in the soil. Therefore, overliming may also induce a decrease in the availability of zinc and cause a deficiency, since the solubility of zinc decreases rapidly at a pH of 6 to 7 (Sanchez, 1976).

Street and Rhue (1980a) indicated that the total zinc content of Florida soils is in the range of 10 to 300 ppm and that, in general, the extractable zinc levels increase with organic matter. Therefore, topsoil may contain approximately four times the amount of zinc found in the subsoil. Large (1971) reported that zinc levels in the soil should be maintained close to 10 ppm; however, the recommendation must take into account soil pH and phosphorus levels since a negative interaction between phosphorus and zinc can occur (Sanchez, 1976).

Popenoe (1960), in his study of the Polochic Valley in Guatemala, indicated that the zinc content of soils is probably in the deficient range, especially when there is less than 1 ppm. Furthermore, an absence of a significant difference in the zinc content at different depths in the soil profile was found.

Historically, the interest in micronutrients such as iron, manganese, copper and zinc comes from problems in soil fertility and plant nutrition. However, in more recent years, there has been much interest in the accumulation of heavy metals in the soil, which are not known to be essential to plants, such ad cadmium, chromium and nickel, in addition to copper and zinc (Soon and Bates, 1982). Prolonged use of pesticides containing heavy metals has led to accumulation of lead, arsenic and copper in agricultural soils, which can cause a serious hazard in the soil-plant-animal system (Soon and Bates, 1982).

Table 4 presents a summary guide to micronutrients with respect to soil pH, soil organic matter, critical soil level quantity, critical levels in the method of extraction, critical and toxic levels in plants and a recommended fertilizer source, according to Gammon (1976).

Mineral Status of Plants

Soil-Plant and Plant-Animal Factors

Of the total mineral concentration in soils, only a fraction is taken up by plants. The availability of minerals in soils depends on their effective concentration in soil solution, representing a dynamic situation in which, as plants remove minerals from the soil, an equilibrium may be restored by the release of minerals from the exchange and surface adsorption sites, from crystalline minerals and other precipitates and from organic matter and microorganisms (Lindsay, 1972; Reid and Horvath, 1980;

TABLE 4. SUMMARY GUIDE TO MICRONUTRIENTS

Micronutrient	Soil pH Increase Effect on Availability	Soil Organic Matter Increase Effect on Availability	Relative Quantity
B	Decreases availability very slowly	Increases availability very little	small-medium
Cu	Decreases availability slowly	Increases availability greatly	small
Fe	Decreases availability intermediately	Increases availability moderately	large
Mn	Decreases availability rapidly	Increases availability slightly	large
Mo	Increases availability rapidly	Increases availability very little	very small
Zn	Increases availability intermediately	Increases availability moderately	medium

	Leaching Loss from Fertilizer	Soil Chelates or Complexes	Critical Soil Level	
			Quantity (ppm)	Method
B	high	low?	0.4	Hot H_2O extraction
Cu	trace	very high?	< 1.0	0.1N HCl extraction
Fe	trace	medium high?	(Soil pH, organic matter, drainage, Mn content, etc. more important)	
Mn	trace	low	5.0 and 15.0	1N HCl and 1N NH_4Ac and 0.2 quinol
Mo	trace	low?	< 0.1 (Soil pH 5.5 or higher)	1N HCl or 1N NH_4OH extraction
Zn	trace	medium	1.0	0.1N NCl extraction

	Critical Level in Plant		Toxic Level in Plant		Fertilizer Sources	
	Ideal-grass	Ideal-legume	Ideal-grass	Ideal-legume	Very Soluble	Reduced Solubility
	ppm					
B	15	30	> 200	> 400	H_3BO_3, $Na_2B_4O_7$	
Cu	2-4	3-7	(Fe deficiency)	---	$CuSO_4$	CuO
Fe	> 40	50	---	---	$FeSO_4$	FeO, Fe_2O_3
Mn	20	40-70	> 500	> 200	$MnSO_4$	MnO, Mn_2O_3, MnO_2
Mo	0.03	0.04-0.3	---	---	$(NH_4)_2MoO_4$, Na_2MoO_4	MoO_3
Zn	< 15	25	> 500	> 500	$ZnSO_4$	ZnO, Zn (metal)

Currently recommended fertilizer rates for Florida pastures

B_2O_3	2.2 kg/ha	MnO	4.5 kg/ha
CuO	4.5 kg/ha	MoO_3	0.1 kg/ha
Fe_2O_3	5.6 kg/ha	ZnO	4.5 kg/ha

[a] Gammon (1976).

Saric, 1983). Therefore, soil properties and conditions such as soil acidity, soil moisture or drainage, soil temperature and seasonal effects, plant genus, species and variety, as well as management and fertilization practices, can affect the uptake and utilization of minerals by crops and pastures (McDowell et al., 1983).

Soil acidity can affect the absorption and distribution of specific minerals in plants as is indicated by Reid and Horvath (1980), who state that as the pH changes, different absorption patterns take place in calcium, phosphorus and magnesium. In addition, pH influences levels of aluminum, manganese and iron. Poor drainage conditions often increase extractable trace elements such as manganese and cobalt (McDowell et al., 1983). Furthermore, soil temperature and season could be other factors affecting the uptake and utilization of minerals by plants as indicated by Nye and Tinker (1977), who reported that the most clearly demonstrated interaction between temperature and mineral uptake appears to be in phosphorus, which is absorbed more slowly at low temperatures, possibly by mechanisms of depressed root extension and membrane permeability. Saric (1983) indicated that the efficiency of utilizing certain mineral nutrients in biomass production is highly related to the genetic specificity of plants. The effect of management and fertilization practices on the uptake and utilization of minerals by plants is described by Beeson (1978), who indicates that at higher inputs, both yield and concentration of minerals increase simultaneously to a certain degree.

Of the thirteen essential minerals obtained from the soil by plants, five are used in relatively large quantities and are thus referred to as macronutrients. These are phosphorus, potassium, calcium, magnesium and sulfur. Plant growth and development may be retarded because these minerals are actually lacking in the soil, they become available too slowly or they are not adequately balanced by other mineral nutrients. The other minerals, iron, manganese, copper, zinc, boron, molybdenum, chlorine and cobalt, are used by higher plants in very small amounts, thereby giving them the designation of micronutrients or trace elements. This designation does not mean that they are less essential than the macronutrients but merely that they are needed in small quantities (Brady, 1974; McDowell et al., 1983).

McDowell et al. (1979) reported that in Latin American countries, mineral deficiencies, imbalances and toxicities are reducing the cattle production in the region, indicating that with the exception of common salt, grazing livestock often do not receive mineral supplements and must depend upon forages to supply their requirements. Furthermore, McDowell et al. (1977a), in a summary of the mineral concentration of 2615 forages in Latin America, indicated that deficiencies were as follows: phosphorus, 86%; sodium, 60%; cobalt, 43%; copper, 47%; and zinc, 75%.

Animal requirements for minerals such as sodium, chlorine, iodine, cobalt and selenium may exceed those requirements of plants (or plants may not need the mineral) to the extent that the element needs to be supplied to the animal by direct supplementation or by fertilization, although no response in crop yield would be expected. On the other hand, plants growing at normal rates may contain sufficient selenium, cadmium, molybdenum and lead to cause toxicity or imbalances in animals (Underwood, 1977).

Macronutrients in the Plant

Phosphorus, as a major nutrient element occurring in all plants, has been considered to be the most prevalent mineral deficient throughout the world (McDowell et al., 1983). In plants, phosphorus is a constituent of many biologically important, organic compounds such as sugar phosphate, ATP and nucleoproteins. Deficiency signs in the plant include chlorosis of older leaves and a characteristic purple coloration that will greatly reduce plant growth (Brady, 1974; Whiteman, 1980).

Plants absorb most of their phosphorus as the primary orthophosphate ion (H^2PO^{4-}); however, small quantities of the secondary ion, $HPO^{4=}$, can also be absorbed. The amounts of these ionic forms in the soil solution are affected by the pH medium surrounding the roots. Therefore, at higher pH concentrations, there is an increase in the amount and absorption of $HPO^{4=}$ by the plant; in contrast, at lower pH values, there is an increase in the amount and absorption of the H^2PO^{4-} ion (Tisdale and Nelson, 1975; Guedes, 1983). Other forms of phosphorus, such as phytin, may be absorbed by the plant roots; however, their importance as a source of phosphorus under field conditions is not well understood (Guedes, 1983).

Reid and Horvath (1980) indicated that increasing soil moisture and temperature will increase the rate of diffusion of phosphorus to the root system, although high levels of soil-water and soil compactation could reduce the amount of oxygen in the soil and, consequently, the active uptake of phosphorus by the plant. There are other factors that could affect phosphorus in the plants. Gomide (1978) reported that the age of the plant is an important factor affecting the chemical composition and nutritive value of forages; phosphorus levels decrease with age. Similar results were indicated by McDowell et al. (1979), suggesting that many grass species containing over .3% phosphorus during early stages of growth will have less than .15% phosphorus as forages mature.

Basak et al. (1982), studying the effects of phosphorus interaction with other mineral nutrients, concluded that combined applications of phosphorus and molybdenum resulted in an increase in concentration and uptake of molybdenum by the plant. Furthermore, differences in phosphorus concentration are apparent between forage classes and species (Reid and Horvath, 1980; McDowell et al., 1983). McDowell et al. (1979) found phosphorus values in 1129 forages from Latin American countries and concluded that 48.4% of the phosphorus values were .2% or less, levels which may be borderline to deficient for most classes of beef cattle (table 5). Scaillet (1969), studying various species of grasses and legumes in several regions of Guatemala, reported differences among species and regions with respect to phosphorus concentration in pastures (table 6).

The main form of phosphorus in most plant sources is phytate phosphorus. Phytate combines with many elements such as calcium, magnesium, manganese and zinc as well as phosphorus, making them, to some degree, unavailable to the animal. The molecular structure is inositol hexaphosphoric acid or phytic acid (IMC, 1978). Therefore, the situation regarding the grazing animal under extensive management systems and on phosphorus-deficient soils may be considerably more critical, particularly when the phosphorus concentration in herbage declines to approximately .10 to .15% dry matter (Reid and Horvath, 1980).

The frequently low availability of phosphorus in tropical soils has been studied by many researchers. Thompson (1978a) reported that phosphorus in several types of vegetation may be easily leached out and that by mid-winter, more than 50% of the phosphorus may be lost. Sousa (1978), in northern Mato Grosso, Brazil, reported that, at different times and different maturity stages, 75% of the grasses contained less than .2%

TABLE 5. MINERAL BREAKDOWN AND CONCENTRATIONS OF 2615 LATIN AMERICAN FORAGES (DRY BASIS)

Element	Percent forages with entries[a]	No. cf entries	Requirement[b]			
Calcium	42.9	1123	.18-.60%	Concentrations, % % of total	0-.30 31.1	over .30 68.9
Cobalt	5.4	140	.05-.10 ppm	Concentrations, ppm % of total	0-.10 43.1	over .10 56.9
Copper	9.0	236	4-10 ppm	Concentrations, ppm % of total	0-10 46.6	over 10 53.4
Iron	9.8	256	10-100 ppm	Concentrations, ppm % of total	0-100 24.1	over 100 75.9
Magnesium	11.1	290	.04-.18%	Concentrations, % % of total	0-.20 35.2	over .20 64.8
Manganese	11.2	293	20-40 ppm	Concentrations, ppm % of total	0-40 21.0	over 40 79.0
Molybdenum	5.1	133	.01 ppm or less	Concentrations, ppm % of total	0 - 3 86.4	over 3 13.6
Phosphorus	43.2	1129	.18-.43%	Concentrations, % % of total	0-.30 72.8	over .30 27.2
Potassium	7.6	198	.60-.80%	Concentrations, % % of total	0-.80 15.1	over .80 84.9
Sodium	5.6	146	.10%	Concentrations, % % of total	0-.10 59.5	over .10 40.5
Zinc	6.9	177	10-50 ppm	Concentrations, ppm % of total	0-50 74.6	over 50 22.4

[a] Less than 1% of the other minerals were included.

[b] Summarized by McDowell et al. (1978).

Source: Latin American Tables of Feed Composition (McDowell et al., 1974; McDowell et al., 1978).

TABLE 6. MEAN ASH AND MINERAL COMPOSITION OF SOME OF THE MORE COMMON GRASS SPECIES IN GUATEMALA

		% dry matter				ppm dry matter			
Species	% Ash	Ca (< 0.3)[a]	K (< 0.8)	Mg (< 0.2)	P (< 0.25)	Fe (< 30)	Cu (< 10)	Mn (< 40)	Reference
Andropogon gayanus (Pasto Gamba)	7.8	0.44	1.56	0.17	0.20	418	20	60	Scaillet (1969)
Axonopus affinis (Grama)	13.5	0.64	--	--	0.12	496	--	--	INCAP (1968)
Brachiaria ruziziensis (Pasto Ruzi)	8.9	0.52	1.93	0.21	0.19	290	33	50	Scaillet (1969)
Cenchrus ciliaris (Zacate Buffel Azul)	11.6	0.37	2.45	0.13	0.20	243	9	34	Scaillet (1969)
Chloris gayana (Zacate Rhodes)	8.6	0.48	1.83	0.16	0.18	300	44	58	Scaillet (1969)
Cynodon spp. (Bermuda Costa)	8.4	0.46	--	--	0.20	--	--	--	INCAP (1968)
Cynodon plectostachyum (Estrella Africana)	7.6	0.62	0.98	0.32	0.16	134	78	64	Scaillet (1969)
Digitaria decumbens (Pangola)	10.4	0.55	--	--	0.15	154	--	--	INCAP (1968)
Echinocloa polystachya (Pasto Alemán)	11.9	1.09	--	--	0.18	217	--	--	INCAP (1968)

TABLE 6 - continued.

Species	% Ash	% dry matter Ca (< 0.3)[a]	% dry matter K (< 0.8)	% dry matter Mg (< 0.2)	% dry matter P (< 0.25)	ppm dry matter Fe (< 30)	ppm dry matter Cu (< 10)	ppm dry matter Mn (< 40)	Reference
Hyparrhenia rufa (Jaragua)	12.2	0.39	--	--	0.10	50	--	--	INCAP (1968)
Lolium perenne (Ryegrass perenne)	10.1	0.61	1.80	0.21	0.25	647	20	97	Scaillet (1969)
Melinis minutiflora (Calinjero)	10.0	0.43	--	--	0.25	117	--	--	INCAP (1968)
Panicum maximum (Pasto Guinea)	12.4	0.42	2.13	0.29	0.25	336	10	66	Scaillet (1969)
Pennisetum clandestinum (Kikuyu)	11.0	0.44	--	--	0.21	209	--	--	INCAP (1968)
Pennisetum purpureum (Napier)	6.2	0.42	1.78	0.13	0.14	264	34	43	Scaillet (1969)
Setaria splendida (Setaria)	9.4	0.30	2.94	0.11	0.13	248	12	120	Scaillet (1969)
Tripsacum laxum (Pasto Guatemala)	9.3	0.29	--	--	0.11	74	--	--	INCAP (1968)

[a] Critical concentrations according to McDowell et al. (1983).

phosphorus, and the highest mean forage phosphorus concentration was .2% during the wet season compared to .08% phosphorus during the dry season. More recently, Vargas (1982), in the Eastern Plains of Colombia, found that the percent of forage samples below critical concentrations of phosphorus for the rainy and dry seasons was 83 and 94%, respectively.

Cohen (1975), trying to explain the high complexity of the relationship between soil, environment, plant nutrient interactions and the incidence of phosphorus deficiency in grazing animals, pointed out that since soils are derived from various soil parent materials, responses to phosphorus supplementation in terms of cattle growth for Australia have been different from those recorded in other continents.

Potassium is second only to nitrogen in the amount absorbed by plants. In plant tissue, it exists as the ion K^+ and is completely water-soluble. For this reason, potassium leaches readily from dead plants which is why organic matter in soils tends to be low in potassium (Rhue and Street, 1980). This element is involved in many plant functions, such as photosynthesis, enzyme activation and plant-water equilibrium. Potassium deficiency in plants results in an increase of leaf and stalk diseases (Brady, 1974; Rhue and Street, 1980).

Total and exchangeable potassium quantities are frequently low in Ultisols and Oxisols in the tropics, and potassium is often a neglected element in pasture fertilization. Successful production of different plant species adapted to high soil acidity has been possible when potassium deficiencies have been corrected (Blue, 1974).

The internal transport of nutrients largely depends upon the synthesis and translocation of photosynthates, which is regulated for nutrient metabolism. However, study of nutrient absorption, distribution and accumulation in various components of grasses in the tropics, with emphasis on nutrient use efficiency, is much less explored. Misra and Singh (1982) studied the effect of soil moisture and clipping stresses on potassium concentration, uptake and deficiency in both temperate and tropical grasses. They found that potassium efficiency was maximum in the case of temperate grasses.

Potassium is considered to function in osmotic processes, the synthesis of protein, the maintenance of protein stability and pH control, although the precise mechanisms by which it accomplishes many of these roles is still far from clear. Potassium is known to be an activator of many enzymes, such as those involved in ATP formation. Some enzymes are known to require potassium at very high concentrations for optimal activity; therefore, it is suggested that potassium ions increase the activity of the potassium-requiring enzymes by changing the conformation of the enzyme molecule in a way which increases the exposure of the active sites. So, it seems likely that one of the reasons for the high potassium requirements of plants may be found in the need for high concentrations of this element by certain enzymes for optimal activity (Hewitt and Smith, 1975; Floate et al., 1981).

Since plants are relatively high in potassium, there is low probability of finding potassium deficiencies in most conventional ruminant diets. However, in tropical regions it is possible that potassium deficiencies could arise in view of the decreasing content of this mineral with increasing forage maturity during the extended dry season (McDowell et al., 1983). Scaillet (1969) indicated that the average content of potassium in different grasses of Guatemala was in the range of 1.5 to 2.5%, although in some regions of the Northwest of the country, the grasses had values of 1% potassium. However, these forage concentrations are higher than the requirements for beef cattle (Scaillet, 1969).

Calcium has many functions in plants, playing an important role in membrane stability, maintenance of chromosome structure and the activation of many enzymes. Calcium may be found in high concentrations in the cell walls as the insoluble salt of pectic acid, which links adjacent chains (Hewitt and Smith, 1975).

In many types of vegetation, the calcium level will remain relatively high throughout the year in contrast to phosphorus. Underwood (1981) indicated that the lower incidence of calcium than of phosphorus disorders is attributed to the following factors: a higher concentration of calcium than phosphorus in the leaves and stems of most plant species; a wider distribution of phosphorus-deficient than of calcium-deficient soils; and a lesser decline in concentration of calcium than of phosphorus with advancing maturation of the plant.

Calcium deficiency suppresses seed development, and necrosis of cotyledons occurs before the maturation of seed in many legumes. Furthermore, root nodule development shows high calcium requirements, which are approximately ten times greater than those needed for normal growth of the host plant with a fixed nitrogen source. Therefore, calcium tends to be immobilized in older tissues so that young leaves suffer from deficiency whereas older ones may remain normal (Hewitt and Smith, 1975; Mika, 1982).

Loosli (1978) indicated that calcium deficiency has not been reported in ruminants grazing native grasses, even without legumes, which are relatively high in calcium. Furthermore, the deficiency has not been reported in grazing beef cattle even during lactation. A similar statement by Reid and Horvath (1980) indicates that calcium deficiency is rare in grazing livestock, unless the pasture contains less than .2% calcium.

Wilson et al. (1981), in their study of the mineral composition of tropical forages using grazing cattle and sheep on calcium-dominated Caribbean soils, indicated that the mineral content of legumes ranged from 1.83 to 2.75% calcium, and the Ca:P ratio for Guinea grass (Panicum maximum) ranged from 2.1 to 3.2. The authors concluded that on calcium-dominated soils which have not been used extensively for forage-animal production, direct mineral supplementation can correct macro- and micromineral imbalances in the animal due to imbalances in forages. McDowell et al. (1979) found calcium values in 1123 forages from Latin American countries and concluded that 68.9% of the calcium values were over .30%, a level which may be borderline to deficient for most classes of beef cattle (table 5).

Magnesium is a readily dissociable ionic activator for many enzymes, and it has a critical role in the structure of the ribosomal particles responsible for protein synthesis. However, it is best known for its role in chlorophyll, where it is in a tetra-pyrrole ring complex. About 3% of the weight of chlorophyll is magnesium, and it enters in protoporphyrin IX which is then condensed with phytol to form chlorophyll a (Hewitt and Smith, 1975). The binding of magnesium in the structure of the ribosomal particles is decreased by chelating agents and by high ionic strength of the medium. Calcium may replace magnesium for binding, but it is less effective in protein synthesis (Hewitt and Smith, 1975).

Reid and Horvath (1980) indicated that the effect of soil acidity per se on availability of magnesium to the plant is difficult to assess and enumerated some of the factors causing magnesium deficiency in plants, such as acid, sandy, highly leached soils, calcareous soils having low magnesium levels, high rates of nitrogen and potassium fertilization, and vegetation having high magnesium requirements. Giving importance to fertilization management since, it has been found that nitrogen fertilization increases the magnesium concentration of herbage in conditions where soil magnesium levels are not limiting and that maybe at the same time, increased potassium content alters the botanical composition of the pasture and depresses the availability of magnesium to the animal. The management and plant factors which may alter the availaibility of magnesium to grazing animals are summarized in table 7.

Sulfur has long been recognized as essential for plant and animal growth. It is already known to be indispensable for many reactions in every living cell. Sulfur is a constituent of the amino acids methionine and cystine, deficiencies of which result in serious animal malnutrition. Furthermore, the vitamins biotin and thiamine contain sulfur, and the structure of proteins is determined to a considerable extent by sulfur groups (Brady, 1974; Hewitt and Smith, 1975).

Atmospheric sulfur dioxide, a by-product of the combustion of sulfur, rich in coals and residual fuel oils, has supplied large quantities of this element to both plants and soils; it is also the ammonium sulfate present in many fertilizers (Brady, 1974). Recently, Milchunas et al. (1983) studied the interaction of atmospheric and soil sulfur on the sulfur and selenium concentration of range plants, and concluded that plant species that accumulated relatively greater quantities of soil sulfur did not necessarily accumulate greater quantities of atmospheric sulfur, and vice versa. The author also found that plant sulfur concentrations increased with increasing time and level of exposure, but the rates of increase in plant sulfur concentrations decreased with increasing sulfur dioxide concentration.

TABLE 7. FACTORS AFFECTING MAGNESIUM UTILIZATION BY RUMINANTS[a]

Factor	Effect
Nitrogen fertilization of forage; application of poultry manure	Interaction of high protein content of forage with potassium to reduce magnesium availability.
Underfeeding and/or low available carbohydrate in diet	May be factors in winter and spring forms of tetany. Protein-energy imbalances may depress magnesium absorption.
Level of magnesium intake from diet	Variable effects on apparent availability. Improved retention at increased intakes.
Other interfering ions	Reports of increased tetany on low sodium pastures. Possible relationship with calcium, phosphorus and manganese.
Complexing of magnesium by dietary components in alimentary tract	Formation of soaps with higher fatty acids. Reaction with organic acids; e.g., citric, transaconitic or plant bacterial cell wall fractions.
Plant species	Different availability of magnesium in grasses vs. legumes, and between species of grass.
Method of conservation	Reduced availability with grass drying; possible improvement with ensiling.
Soil ingestion	Decreased loss of magnesium in feces and increased absorption and retention.

[a] Reid and Horvath (1980).

Miles and McDowell (1983) stated that sulfur supplementation studies for grazing livestock are needed, since recent reviews have indicated that feed intake, milk and meat production increase tremendously with sulfur supplementation.

Shirley (1978) reported that plants can reduce sulfate to sulfide as indicated by their growth with sulfate as the only source of sulfur, and that concentration of sulfur in plants depends largely on the amount of sulfur in the plant protein.

Micronutrients in the Plant

Although the amount of iron required by plants is very low, it has been known for years to be essential for normal plant growth. Iron is a constituent of some enzymes and carriers which operate in the respiratory mechanism of living cells (Brady, 1974; Nishio and Terry, 1983).

There are electron transport enzymes containing metals capable of valence change. However, there is some uncertainty about the behavior of iron in chloroplast ferridoxin, which has two iron atoms and transfer electrons singly as proven in resonance studies, indicating that one iron atom is converted to Fe^{+2} by reduction while the other remains in the ferric state (Hewitt and Smith, 1975). Recently, new studies are giving more attention to the function of resupplying iron to iron-deficient plants and its response on chloroplast membrane development; the results show that the chloroplast development system provides a useful approach in studying biomembrane synthesis (Nishio and Terry, 1983).

Iron-zinc interaction has been reported in many crops and pastures. Some researchers observed that competition for root absorption sites exists between Fe^{+3} and Zn^{+2}, while other studies reported that inhibitory effects of iron and zinc absorption were non-competitive and that translocation of zinc decreased with increased iron levels. Verma and Tripathi (1983) stated that when more zinc was applied, less zinc was translocated to grains, and when more iron was applied, more zinc was translocated to grains.

McDowell et al. (1983) reported that the majority of tropical soils are acid, a condition which favors availability and plant uptake of iron, resulting in forage levels of this mineral generally in excess of requirements. However, certain forages are marginal in iron in relation to cattle requirements, mainly in those areas where cattle are fed on straw for extended periods. According to Underwood (1966), the iron content of herbage plants is a reflection of the species and type of soil upon which plants are grown. McDowell et al. (1978) indicated that iron deficiency is considered rare for grazing cattle due to generally adequate pasture concentration, together with contamination of plants by soils. Scaillet (1969) found that the iron content of forages in Guatemala ranged from 200 to 750 ppm on dry matter basis and that species of forage in the highlands contained higher concentrations.

Manganese is one of the essential elements required for normal plant growth and appears to be a very important catalyst, being an activator of such enzyme systems as dehydrogenases and carboxylases (Hewitt and Smith, 1975; Street and Rhue, 1980a). Thomas (1970) stated that manganese is a required ion in the cell-free system of plants which incorporate xylose, galactose and the amino acid serine into the mucopolysaccharides.

Street and Rhue (1980a) reported that for most crops, manganese deficiency normally occurs when plant tissue concentration is less than 20 ppm in dry matter; in contrast, toxicity occurs at levels in excess of 500 ppm for many plant species. Manganese deficiency in plants can be prevented by applying a manganese fertilizer to the soil and controlling the pH (Street and Rhue, 1980a). McDowell et al. (1978) reported that in Latin America, there is a data scarcity concerning manganese content in forages and that only 11.2% of the 2615 forages in the 1974 Latin American Tables of Feed Composition (McDowell et al., 1974) contained manganese values. Lang (1971), in Costa Rica, indicated that regions which are characterized by volcanic soils had high manganese concentrations in forages and that a low reproduction performance in cattle has been observed. In contrast, in Guatemala, only one of 28 forage species had mean manganese values of less than 20 ppm, a level which is considered to be borderline to deficient for most classes of beef cattle (Scaillet, 1969).

Copper is a constituent of certain oxidizing-reducing enzymes such as ascorbic acid oxidase and tyrosine. Therefore, it serves as a catalyst in plant metabolism (Hewitt and Smith, 1975). In forage plants, a great part of the copper exists in bound form as water-soluble organic complexes. An aqueous extract from fresh forage contains a small proportion of the copper as free ions or as postively charged complexes; the greater part exists in the form of neutral or negatively charged complexes (Coelho, 1978).

One approach to the alleviation of copper and other mineral deficiencies in grazing animals is to improve the balance of mineral elements in the herbage. This may be achieved by soil or foliar application of the deficient element or by adjustment of the botanical composition of the herbage in favor of species or varieties which have higher contents of the element in question (Gladstone et al., 1975). Soil and foliar applications of copper sulfate and copper oxide to grassland have produced little or no lasting benefits in terms of herbage copper concentration

(Reith, 1973). Herbage species are known to differ in copper concentration; in particular, legumes tend to be richer in copper than grasses (Gladstone et al., 1975). However, Forbes and Gelman (1981) concluded that adjustment of botanical composition, with or without copper sulfate application, will not help to prevent hypocupremia in grazing stock.

Underwood (1981) points out that copper deficiency in livestock occurs on a wide range of soil types. Since many forms of copper imbalance in ruminants are brought about by interfering factors such as molybdenum, sulfur, calcium, zinc and iron, concentrations may also vary with soil characteristics, fertilizer usage and grazing system. Beeson and Matrone (1976) point out that a high organic matter content in soils is frequently associated with poor drainage and high water quantities; such conditions favor the uptake of molybdenum by plants. According to Reid and Horvath (1980), the levels of copper and molybdenum in forage plants are affected not only by soil properties and soil amendments but also by plant species, stage of growth and plant part. Although not all reports agree, concentrations of copper and molybdenum tend to decrease with advancing maturity, and this decline, with respect to maturity, is continuous in grasses but not with legumes (Fleming, 1973). However, copper in fresh herbage has been shown to be less available than in hay made at the same growth stage (Reid and Horvath, 1980).

McDowell et al. (1983) reported that with the exception of phosphorus, copper deficiency is the most severe mineral limitation to grazing livestock throughout extensive regions of the tropics. Whitehead (1966) cited that normal concentrations of copper, molybdenum and sulfur in herbage species were 2 to 15 ppm, .1 to 4 ppm and .20 to .45%, respectively. However, Cunha (1973) stated that copper deficiencies usually occur when forage molybdenum exceeds 3 ppm and the copper level is less than 5 ppm. Furthermore, Lessard et al. (1970) concluded that sulfur values higher than .35% in forage were often associated with hypocupremia in animals. Scaillet (1969) reported levels of copper in forages from Guatemala in the range of 10 to 50 ppm, dry matter basis.

Zinc, like copper, appears to function as a catalyst in plant metabolism. It is a constituent of the enzyme carbonic anhydrase, as well as a variety of dehydrogenases, proteinases and peptidases (Price et al., 1972). Street and Rhue (1980b) indicated that zinc deficiencies have been verified as one of the most common occurring in agricultural crops and that the form of zinc used by plants is the divalent metallic ion, Zn^{+2}. Underwood (1981) reported that zinc concentration in plants decreases with advancing maturity. Furthermore, legumes carry higher zinc concentrations than grasses grown and sampled under the same conditions.

Recent studies about chemical distribution and plant availability of cadmium, nickel and zinc in polluted soils indicated that there is a correlation between soil mineral content and plant concentrations of cadmium and zinc (Soon and Bates, 1982).

Deficiency symptoms of zinc are very similar to those of magnesium, manganese or iron, in which chlorotic zones on leaves are found (Street and Rhue, 1980b). Zinc deficiency may have effects on auxin metabolism, in which peroxidase usually increases in zinc-deficient tissues and auxin destruction is augmented (Hewitt and Smith, 1975). The amount of zinc needed by plants is very small. A zinc deficiency is considered when leaf tissue concentration is less than 20 ppm on a dry matter basis (Rhue and Street, 1980). The same authors indicated that the normal concentration range for zinc is between 25 and 150 ppm while toxicity levels occur when leaf tissue exceeds 450 ppm. From 177 forage averages in the 1974 Latin American Tabled of Feed Composition (McDowell et al., 1974), 61.5% contained values of less than 40 ppm zinc in the dry matter (McDowell et al., 1978).

There is no evidence that boron is a component or an activator of any enzyme, and its role is still the least understood of all the essential elements (Hewitt and Smith, 1975). Not a great deal is known regarding the specific role or roles of boron in the metabolism of plants, although there is strong evidence in support of the theory that boron functions in the translocation of sugars. It has also been suggested that boron regulates the cyclic oxidation in tyrosine systems and that it is essential for phosphorylating reactions (Hewitt and Smith, 1975). Furthermore, Brady (1974) reported that boron deficiency decreases the rate of water absorption and translocation of sugars in plants, playing an important role in the reproduction of plants and germination of pollen.

According to Hewitt and Smith (1975), phenol oxidases increase abnormally in boron-deficient tissues, but monophenols and o-diphenols such as chlorogenic acid and caffeic acid also accumulate, making the overall picture complex. Monophenols are auxin oxidase activators and o-diphenols are inhibitors. Therefore, boron may influence their ratio by controlling (inhibiting) some aspects of phenolase activity and thereby indirectly influencing auxin oxidation, lignin synthesis and other reactions.

Molybdenum has been found to be essential for certain nitrogen transformation in microorganisms as well as in plants. It is known to be essential for the process of nitrogen fixation, and it must be present in plants if nitrates are to be metabolized into amino acids and proteins (Brady, 1974; Coelho, 1978).

As previously stated, according to Underwood (1981), copper deficiency can arise when high intakes of molybdenum and sulfur occur coupled with normal copper intakes. Reid and Horvath (1980) reported that at high dietary molybdenum concentrations (20 to 100 ppm), molybdenosis occurs in grazing animals which respond to copper supplementation. According to McDowell and Conrad (1977), widespread copper deficiency in ruminants has been reported in tropical countries, but it is not clear whether the deficiency is conditioned by high levels of molybdenum and/or sulfur in the soil and forages.

Cobalt is essential to the symbiotic fixation of nitrogen. This element is a component of vitamin B_{12}, which is thought to be necessary for the formation of a type of hemoglobin in nitrogen-fixing nodule tissue (Brady, 1974). In addition, legumes and other plants are thought to have a cobalt requirement independent of nitrogen fixation, although the amount required is small compared to that for the nitrogen fixation process (Houser et al., 1978).

Houser et al. (1978) discussed the factors affecting the availability of cobalt to plants and concluded that overliming, and the subsequent rise in soil pH, renders cobalt almost completely unavailable to plants. In addition, they suggested that plants grown on a soil with 15 ppm cobalt, which is considered neutral or slightly acid, may contain more cobalt than those grown on 40 ppm alkaline soils.

Plants have varying degrees of affinity to cobalt, some being able to concentrate the element much more than others. Legumes generally have more ability to concentrate cobalt than grasses, and most of the cobalt present in plants tends to concentrate in the leaves (Houser et al., 1978).

Whitelaw and Russell (1979), in reviewing methods of prophylaxis for cobalt deficiency in ruminants, cited critical herbage concentrations of less than .1 ppm in the dry matter. Similar information is cited by Houser et al. (1978), indicating that since the level of cobalt found in forages is determined by many factors, the level of cobalt in forages is a much more useful tool in measuring its adequacy. There seems to be a direct relationship between cobalt in forage and the health of ruminants grazing that forage. Houser et al. (1978) also stated that it appears that less than .1 ppm in the forage should be considered cobalt-deficient. However, Latteur (1962) reported the common levels of cobalt deficiency in forages which could affect ruminant status as follows: .01 ppm, extremely deficient; .04 to .07, insufficient; .07, the lowest limit to health; and .1 to .3 ppm, adequate to increase productivity.

Selenium is closely related to sulfur and probably enters the plant by a similar mechanism to form the selenium-containing analogues of cysteine and methionine (Hewitt and Smith, 1975). Ammerman et al. (1978) found that selenium concentration of forages is depend on soil factors, plant species, stage of maturity, yield, pasture management, climate and soil pH. Furthermore, he suggested that total selenium content of soils has shown very little relationship to the concentration of selenium in the plants grown on it; this is probably due to the fact that selenium in the soil is present in chemical forms which vary widely in availability to plants. A similar suggestion was made by Underwood (1977), who considered that for all ordinary grasses and legumes, the primary determinant of selenium concentration is the level of available selenium in the soil. Reuter (1975) reported that waterlogging and high rainfall are factors contributing to selenium deficiency. According to Ammerman et al. (1978), pasture management involving liming and selenium-containing fertilizer can be extremely beneficial to increasing forage selenium concentrations; however, overliming can accentuate selenium toxicity for livestock in a seleniferous region by increasing plant concentration of this element.

The differences in selenium concentration between accumulator and non-accumulator plants are marked, but differences between non-accumulator forage species may be minor (Underwood, 1977). In certain regions, accumulator plant species containing over 1000 ppm of selenium are found growing alongside grasses containing less than 10 ppm (Beeson, 1961). Acute selenium poisoning is most often associated with consumption of selenium accumulator plants such as Astrogalus racemous, which may contain from 100 to over 10,000 ppm selenium.

Evidence for an association of soil characteristics and selenium deficiency or toxicosis in tropical regions is scanty. McDowell (1976) stated that it seems inconceivable to suppose that the huge land masses included in the category of developing countries would not have extensive selenium-deficient areas in addition to selenium-toxic areas. Furthermore, of 3990 feeds included in the 1974 Latin American Tables of Feed Composition (McDowell et al., 1974), there were selenium values for only .06% of the samples. Cox (1973) noted that most of the soils of Latin America are acid, not alkaline, soils which normally do not produce plants containing toxic concentrations of selenium. Therefore, it might be expected that in Latin America, selenium-deficient regions would be more prevalent than seleniferous regions.

Mineral Status of Ruminants

Occurrence and Assessment of Mineral Status in Grazing Ruminants

Ruminants, like all other animals, must receive all of the essential dietary nutrients, including water, in optimum amounts to maintain health, to grow and to reproduce at their potential levels (Loosli, 1978). However, all mineral elements, whether essential or nonessential, can adversely affect an animal if included in the diet at excessively high levels. Without question, tolerance levels vary from animal to animal and even from day to day in the same animal. Many other factors, such as age, physiological status of the animal, nutritional status, levels of various components and biological availability, influence the level at which a mineral element could be deficient or could cause adverse effects (NRC, 1980).

Various comprehensive survey studies of the occurrence of mineral deficiency and toxicity diseases in livestock, as related to mineral levels in pasture and soil characteristics, have been attempted by many researchers. However, in several instances, the problems identified were "frank deficiencies"; therefore, in 1956, Russell and Duncan (cited by Reid and Horvath, 1980) suggested the need to consider the importance of "borderline" conditions. They also recommended use of a comprehensive approach, based on examination of soil, plant and animal factors, in solving mineral imbalance problems. Similarly, McDowell and Conrad (1977) have described the development of a mapping survey technique, involving analysis of soil, forage and animal tissue samples, for the identification of mineral disorders in livestock in Central and South America.

An analysis of the mineral content of plants consumed by grazing animals can be helpful in predicting the mineral status of grazing ruminant animals. Furthermore, tremendous variations occur in the mineral content of these plants, depending on plant species, stages of maturity and soil types in which they are grown. In addition to animal factors such as intake, absorption and secretion of mineral elements must be considered (Conrad, 1978).

Ideally, animal researchers would like to determine the mineral status of animals by measuring the mineral content of a tissue which is readily available from a live animal (Conrad, 1978). Since homeostatic control of mineral utilization is exercised in different ways for different elements, it is important to select organs or fluids for analysis which reflect the nutritional status of the animal (Reid and Horvath, 1980). A summary of an appropriate sampling approaches of the tissues and fluids of the greatest value in detecting various mineral deficiencies is presented in table 8 (Conrad, 1978). The critical levels of some minerals are shown in table 9 (McDowell et al., 1983).

When the mineral requirements of grazing ruminants are considered, the contribution of soil ingested directly by the animal is seldom taken into account (Conrad, 1978; Reid and Horvath, 1980). Thornton (1974) calculated from observations in England that soil ingested by cattle provided approximately ten times the amount of copper, lead and arsenic supplied by herbage. Furthermore, Reid and Horvath (1980) discussed general considerations concerning plant and animal requirements which are summarized in table 10. At the same time, mineral requirements of cattle as related to plant requirements are presented in table 11 (Reid and Horvath, 1980).

TABLE 8. SAMPLES REQUIRED AND COMPONENTS TO BE ESTIMATED IN TRACING DIFFERENT DEFICIENCIES

Mineral deficiency	Soil	Diet	Liver	Component in: Blood plasma	Bone	Saliva	Milk	Urine	Other
Calcium		$\underline{\mathrm{Ca}}^{a}$			Ca				
Phosphorus		$\underline{\mathrm{P}}$		$\underline{\mathrm{P}}$	$\underline{\mathrm{P}}$				
Magnesium		$\underline{\mathrm{Mg}}$, $\underline{\mathrm{K}}$, $\underline{\mathrm{N}}$		Mg				Mg	
Sodium		$\underline{\mathrm{Na}}$				$\underline{\mathrm{Na}}$, $\underline{\mathrm{K}}$			
Cobalt	Co	$\underline{\mathrm{Co}}$	Co, vit. B_{12}						serum vit. B_{12}
Copper			$\underline{\mathrm{Cu}}$	$\mathrm{Cu}^{b,c}$					
Iron									Hb^{d}
Iodine							$\underline{\mathrm{I}}$		
Manganese		$\underline{\mathrm{Mn}}$, $\underline{\mathrm{Ca}}$, $\underline{\mathrm{P}}$	Mn						
Selenium			$\underline{\mathrm{Se}}$	Se					kidney cortex
Zinc		$\underline{\mathrm{Zn}}$		Zn					

[a] Underlined indicates greatest value according to Conrad (1978) and CMN (1973).

[b,d] Percent saturation of transferrin, hemoglobin and hematocrit of blood.

[c] Also plasma ceruloplasmin.

TABLE 9. DIAGNOSIS OF SPECIFIC MINERAL DEFICIENCIES OR TOXICITIES IN CATTLE

Element	Animal requirement		Tissue	Critical levels[a,b]
	Dairy cow[c]	Beef cattle[d]		
Deficiency				
Calcium	.54%	.18-1.04%	Bone (fat free)	24.5%
			Bone ash	37.6%
			Plasma	8 mg/100 ml
Magnesium	.20%	.04-.10%	Serum	1-2 mg/100 ml
			Urine	2-10 mg/100 ml
Phosphorus	.38%	.18-.70%	Bone (fat free)	11.5%
			Bone ash	17.6%
			Plasma	4.5 mg/100 ml
Potassium	.80%	.60-.80%		
Sodium	.18%	.06%	Saliva	100-200 mg/100 ml
Sulfur	.20%	.10%		
Cobalt	.10 ppm	.05-.10 ppm	Liver	.05-.07 ppm
Copper	10 ppm	4 ppm	Liver	25-75 ppm
			Serum	0.65 μg/ml
Iodine	.50 ppm		Milk	300 μg/day
Manganese	40 ppm	1-10 ppm	Liver	6 ppm

TABLE 9 - continued.

Element	Dairy cow	Beef Cattle	Tissue	Critical levels[a,b]
Selenium	.1 ppm	.1 ppm	Liver Serum Hair	.25 ppm .03 µg/ml .25 ppm
Zinc	40 ppm	20-30 ppm	Serum	.6-.8 µg/ml
Toxicity				
Copper	80 ppm	115 ppm	Liver	700 ppm
Fluorine	30 ppm	40 ppm[e]	Bone	4,500-5,500 ppm
Manganese	1000 ppm	150 ppm	Hair	70 ppm
Molybdenum	6 ppm	10 ppm[e]	Liver	4 ppm
Selenium	5 ppm	5 ppm	Liver Hair	5-15 ppm 10 ppm

[a] References for critical levels are found in the following reviews: McDowell (1976); Mtimuni (1982); McDowell et al. (1983).

[b] Non-mineral assays for the following elements are sensitive diagnostic techniques: cobalt (vitamin B_{12}), iodine (free thyroxine), copper (ceruloplasmin) and selenium (glutathione peroxidase).

[c] Recommendations for lactating dairy cows (500 kg) giving 17-23 kg milk (NRC, 1978).

[d] Recommendations for growing, fattening steers and heifers (NRC, 1976).

[e] NRC (1980).

TABLE 10. GENERAL CONSIDERATIONS CONCERNING PLANT AND ANIMAL REQUIREMENTS

Element	Requirement for Plant versus Animal	Response in the plant and/or in the animal
Manganese Potassium Zinc	Plant greater than animal	Animal growth would not normally be limited by a deficiency of the element
Chlorine Cobalt Iodine Sodium Selenium	Plant less than animal	Elements need to be supplied to the animal by direct supplementation
Phosphorus	Plant approx. equal animal	Deficiency of the element affects the growth of plants and animals
Cadmium Lead Molybdenum Selenium	Plant normal and animal toxic	Imbalance in animals

Source: Reid and Horvath (1980).

TABLE 11. MINERAL REQUIREMENTS OF CATTLE AND CRITICAL LEVELS OF MINERALS FOR PLANT GROWTH

Mineral	Animal requirement		Plant requirement		
	Dairy Cow[a]	Beef Cattle[b]	Alfalfa[c]	White clover[d]	Perennial rye grass[d]
Phosphorus, %	.38	.18-.70	.25-.50	.30-.40	.28-.36
Potassium, %	.80	.60-.80	1.20-2.50	1.8-2.3	2.0-2.5
Calcium, %	.54	.18-1.04	1.7-2.50	.5-.8	.2-.3
Magnesium, %	.20	.04-.10	.25	.12-.14	.10-.13
Sodium, %	.18	.06	.01-.24	.2-.3	.2-.5
Sulfur, %	.20	.10	>.20	.25-.30	.25-.30
Iron, ppm	50	10	30	50-70	50-70
Manganese, ppm	40	1-10	>15	25-35	25-35
Zinc, ppm	40	20-30	20-50	12-18	10-16
Copper, ppm	10	4	5-16	4-6	4-6
Cobalt, ppm	.10	.05-.10	.02-.03		
Iodine, ppm	.50				
Molybdenum, ppm			.4-2.0	.1-.3	.1-.3

[a] Recommendations for lactating dairy cows (500 kg) giving 17-23 kg milk (NRC, 1978).

[b] Recommendations for growing, fattening steers and heifers (NRC, 1976).

[c] Intermediate status for whole top alfalfa at 1/10 bloom cut at base.

[d] Critical range (minimum concentrations for maximum yield) in leaves of white clover and perennial ryegrass at grazing height (Reid and Horvath, 1980).

Calcium and Phosphorus

Calcium is the fifth most abundant element in the earth's crust and the most abundant cation in the animal body, comprising 1 to 2% of the total weight (NRC, 1980). Similarly, phosphorus is the second most abundant mineral element in the animal body. These are major constituents of bone and teeth, and their roles in numerous other physiological and biochemical processes are crucial to the well-being of all animals (Underwood, 1981).

Naturally occurring deficiencies of calcium and phosphorus in domestic animals usually develop in quite different circumstances. However, calcium deficiency is more a problem of hand-fed animals, especially pigs and poultry, whereas phosphorus deficiency is predominantly a condition of grazing livestock, especially cattle (Underwood, 1981).

About 99% of the calcium and 80% of the phosphorus are found in bones and teeth; the remaining 1% calcium and 20% phosphorus are widely distributed in the fluids and soft tissues of the body, where they serve a range of essential functions. Calcium occurs as a free ion, bound to serum proteins and complexed with organic and inorganic acids (Underwood, 1981). Furthermore, since calcium is required in large quantities for skeletal development, calcium requirements are highest during periods of rapid skeletal growth and during periods of lactation (Conrad, 1978). Phosphorus is probably the most protean of all mineral elements. In addition to its role in the development and maintenance of skeletal tissue, this element has been found in the soft tissue, playing vital metabolic roles in carbohydrate metabolism in the formation of hexose phosphate, creatinine phosphate, adenylic acid and in protein metabolism where it is present in nucleo-proteins and phosphoproteins (Irving, 1973; Conrad, 1978; Underwood, 1981).

Normal metabolism of calcium and phosphorus requires an adequate supply of vitamin D which is involved in the intestinal absorption of these minerals (Irving, 1973; Underwood, 1981). Therefore, a severe dietary deficiency of calcium or phosphorus, or lack of vitamin D which impairs their absorption and utilization, causes inadequate calcification of the growing skeleton and other deviations in bone development, of which the best known is rickets in young cattle. In contrast, in mature cattle, excessive demineralization of the skeleton occurs and osteoporosis may result (CMN, 1973). Furthermore, Underwood (1981) indicated other changes such as impaired fertility, decreased milk production, and depressed appetite and efficiency of feed use with development of pica or depraved appetite.

In normal metabolism, vitamin D is converted to 25-hydroxycholecalciferol (25-OH D) and then to 1,25 dihydroxycholecalciferol (1,25 (OH) 2 D) in the kidney prior to exerting its potent calcium mobilization action on bones and the intestine (De Luca, 1974; Haussler, 1976). Failure of the kidneys to biosynthesize sufficient 1,25 $(OH)_2$ D was suggested as a possible explanation for parturient hypocalcemia, a metabolic disease associated with parturition and the initiation of lactation which is characterized by hypocalcemia, hypophosphatemia and hypomagnesemia. However, as Horst et al. (1979) demonstrated, the kidney is responsible for this hypocalcemia; for this reason, it was proposed that parturient hypocalcemia results from an unexplained organ resistance to one of the calcium-mobilizing hormones (De Luca, 1977).

According to Thompson (1978a), it has been known for over 50 years that an interrelationship exists between calcium and phosphorus. The desirable calcium-to-phosphorus ratio has been defined as

2:1; however, when calculi problems are encountered, a higher ratio (7:1) may be advisable (NRC, 1976). The NRC (1980) also stated that calcium compounds ingested orally are usually not considered toxic to the animal since the homeostatic mechanism tends to protect against the absorption of excessive quantities of the element. The feeding of high levels of calcium for long period of time can have detrimental effects on animal performance due to the interrelationship with other nutrients, especially phosphorus (NRC, 1980). Furthermore, as Maynard et al. (1979) reported, chronic intakes of high dietary calcium may also cause hypersecretion of calcitonin, bone abnormalities such as osteopetrosis (dense bones) and formation of kidney stones.

Blood plasma calcium and phosphorus

Underwood (1981) considered calcium levels in blood plasma a good indicator of the calcium status of grazing animals and suggested 9-11 mg calcium per 100 ml blood plasma as the normal level (table 9). Since blood calcium is controlled by the parathyroid hormone calcitonin (Guyton, 1966) and 1,25 (OH)2 cholecalciferol (Boris et al., 1978), only in extreme deficiency could blood calcium be low (CMN, 1973). According to Cunha et al. (1964), values of 10-12 mg/100 ml in blood serum are normal for healthy cattle, with deficiency occurring when these values fall below 8 mg/100 ml.

Recent studies by Greene et al. (1983), studying the effect of feed on calcium and phosphorus contents in blood serum and saliva of wethers, demonstrated that calcium and phosphorus contents in serum and saliva are influenced not only by different supplies but also by the time of sampling.

Normal values for plasma inorganic phosphorus are 4-6 mg/100 ml for adults and somewhat higher, often 6-8 mg/100 ml, for very young animals

(Underwood, 1981). According to Underwood (1966), the most sensitive and earliest biochemical measure of phosphorus deficiency is a reduction in serum inorganic phosphorus. However, the CMN (1973) did not consider serum inorganic phosphorus to be sufficiently sensitive to recommend it for diagnosis in cattle, because phosphorus in blood plasma varies widely and the factors of this variation are not well understood.

There are many factors which could affect the amount of phosphorus in plasma (Irving, 1973). The phosphorus level in blood is not nearly as constant as the calcium level. This is not difficult to understand since blood phosphorus is in equilibrium, not only with bone phosphorus, but with that arising from a large number of organic phosphorus compounds produced as a result of cellular metabolism (Irving, 1973). Little et al. (1971) reported that the rise in inorganic phosphorus of blood plasma, which occurs with time, is due to hydrolysis of organically combined phosphorus, such as adenosine triphosphate. In addition, dietary factors could affect both blood calcium and phosphorus, as was demonstrated by Little (1972) and Irving (1973).

Phosphorus values are also affected by parasites. Blood phosphorus could increase from 5.08 mg/100 ml to 9.01 mg/100 ml in liver fluke-infested White Fulani cattle in Nigeria (Ogunrinade et al., 1980, cited by Mtimuni, 1982). Similarly, blood phosphorus increases with exercise, as was postulated by Gartner et al. (1965).

Usually, the first evidence of phosphorus deficiency is a drop in plasma inorganic phosphorus below the normal levels of 4-6 mg/100 ml for adults and 6-8 mg/100 ml for young animals (Thompson, 1978a). Conrad (1978) suggested that most research groups consider serum inorganic phosphorus to be sufficiently sensitive and recommend it for diagnosing phosphorus deficiencies, while the CMN (1973) recommends forage analysis. It is apparent that both serum inorganic phosphorus and forage analyses are effective in determining the phosphorus status of ruminants (Conrad, 1978).

Bone calcium and phosphorus

Bone mineral has an amorphous or noncrystalline phase which is hydrated (tricalcium phosphate) and a crystalline phase that resembles hydroxyapatite (Maynard et al., 1979). Since there is little variation in the elementary composition of bone ash and the calcium and phosphorus usually occur in approximately a 2:1 ratio (Maynard et al., 1979), many researchers suggest that bone provides a more reliable method for assessing calcium and phosphorus than blood (Cohen, 1973).

The nature of the diet can affect somewhat the mineral relationship in bone, even though the ash content is not appreciably changed (Maynard et al., 1979). Furthermore, Maynard et al. (1979) described that in mammals, bone is made of approximately 36% calcium, 17% phosphorus and .8% magnesium, based on dry, fat-free bone. Similar results were reported by Ammerman et al. (1974), who investigated the mineral composition of different tissues of beef cattle under grazing conditions in Panama and found values for calcium from 37.6 to 38.2% and for phosphorus, from 17.6 to 18.1% in bone ash. Recently, in Bolivia, Peducassé et al. (1983), in a survey to determine the mineral status of beef cattle during the dry season, found that 96% of the bone samples had calcium levels less than 34% in the bone ash, and 45% of the bone samples had values less than 17% phosphorus. More dramatic results were reported by Vargas (1982) in the tropical savanna of the Eastern Plains of Colombia.

Little (1972) suggested that calcium or phosphorus content per unit volume has greater sensitivity than per unit of fresh weight, moisture-free and fat-free basis, since in the last two, contents of water and fat were not taken into account. Values of 120 mg phosphorus per ml bone from the 12th rib indicate deficiency, and levels greater than 150 mg/ml phosphorus indicate adequacy (Little and Shaw, 1979).

Magnesium

Magnesium is closely associated with calcium and phosphorus, both in its distribution and in its metabolism (Maynard et al., 1979). Approximately 60% of total body magnesium is located in the bone, where the function of the element is not known. About one-third of that in the bone is combined with phosphate, and the remainder is adsorbed on the surface of the mineral structure (NRC, 1980). The other 40% of the magnesium is widely distributed in the various fluids and other soft tissues (Maynard et al., 1979). The small amount present in extracellular fluid is exchanged easily with that adsorbed on the bone surface (NRC, 1980).

As well as serving as an essential constituent of bones and teeth, magnesium is required for various body processes, notably as an activator of various enzymes, and is essential for cellular respiration (Maynard et al., 1979; NRC, 1980). Magnesium is necessary for all phosphate transfer reactions and, in certain tissues, it is complexed with adenosine triphosphate, adenosine diphosphate and adenosine monophosphate. Also, it is an activator for all thiamine pyrophosphate-requiring reactions (NRC, 1980).

The principal site of magnesium absorption in ruminants is the reticulorumen (Tomas and Potter, 1976). Absorption can be affected by conditions such as high pH, where a high pH resulting from high ammonia concentration reduces magnesium absorbability (Fenner, 1979). The magnesium in bone can be mobilized to a limited extent in young animals; in contrast, in older animals mobilization is very limited (NRC, 1980).

Dietary magnesium requirements of livestock vary with the species, breed of the animal, age, rate of growth and with the biological availability of the mineral in the diet (Underwood, 1981). However, dietary magnesium requirements are influenced by several other factors, including the protein content of the diet and the magnesium status of the animal (Hendricks et al., 1970, cited by Underwood, 1981).

The minimum growth requirements for sheep and cattle can generally be met by pastures containing .07% magnesium, dry basis (Underwood, 1981). The NRC (1976) stated requirements for growing, fattening steers and heifers of .04 to .1% magnesium (table 11). A higher proportion of magnesium is considered necessary for lactating cows (Conrad, 1978; Underwood, 1981). Requirements of lactating beef cows have been determined to be approximately .18% of dietary dry matter (NRC, 1976).

In ruminants, a magnesium-dependent condition known as grass tetany, grass staggers, hypomagnesemic tetany and lactation tetany is frequently a problem in ruminants grazing excellent, high quality pasture during the fall and spring months (Conrad, 1978). The pasture on which the animals develop the grass tetany is not usually low in magnesium; therefore, there must be other factors related to magnesium utilization in ruminants (Underwood, 1981). The U.S.D.A. Grass Tetany Workshop (Grunes and Mayland, 1975) reported that in the United States, tetany is primarily a problem in beef cattle and may show up as 1) a winter condition, related in part to an absolute deficiency of magnesium in winter forage and to restricted feeding in early lactation; 2) "wheat pasture poisoning" syndrome in beef animals grazing small-grain pastures which may contain low levels of magnesium and high concentrations of potassium and nitrates; or 3) the classical spring tetany on grass pasture, which may be associated with seasonal weather patterns and the use of fertilizer on pastures. The annual losses in the United States are in the range of 1 to 2% of the grazing animal population, with high incidence areas with values greater than 30%.

Blood plasma magnesium

Generally, the high intake of magnesium increases blood serum magnesium (NRC, 1980). According to the CMN (1973), the magnesium status of the animal is best assessed from magnesium levels in blood and urine. McDowell et al. (1983), in a summary of the diagnosis of specific mineral deficiencies and toxicities in cattle, reported that serum magnesium levels of 1 to 2 mg/100 ml are considered deficient, and a level of less than 1 mg/100 ml indicates danger of tetany (table 9). However, Underwood (1981) considered 1.8 to 3.2 mg/100 ml serum magnesium as the normal range for cattle. Similarly, the CMN (1973) suggested that the approximate normal level of serum magnesium in cattle is 2 to 3.5 mg/100 ml. Below the level of 2 mg/100 ml magnesium, deficiency begins, with 1 mg/100 ml considered an extreme deficiency.

Kiatoko (1976) reported blood plasma magnesium levels of 1.8 to 1.9 mg/100 ml in cattle from two different regions of Costa Rica. However, Chicco et al. (1973) indicated that high dietary calcium depressed magnesium content in bone and plasma and, therefore, decreased magnesium utilization. Furthermore, high levels of supplemental magnesium resulted in depressed feed intake, elevated serum magnesium and diarrhea (NRC, 1980).

Bone magnesium

Normal magnesium concentrations in rib bone of cattle range from .67 to .7% (Blaxter and Sharman, 1955). Similarly, Lebdosoekojo (1977) reported values for magnesium in rib bone between .60 and .73% in bone ash from young bulls under grazing conditions in the Eastern Plains of Colombia. Sousa (1978), in Brazil, examined rib bone magnesium levels from different ranches and found values slightly below normal levels, yet they were higher than those encountered in animals manifesting grass tetany.

The hypomagnesemia with tetany that arises suddenly in animals raised on spring grass pastures is not accompanied by any gross fall in skeletal magnesium, and a complete remission can be obtained by a single injection of magnesium (Underwood, 1981).

Sodium, Potassium and Chlorine

It is convenient to consider sodium, potassium and chlorine together, due to the broad similarities in their function and requirements in the animal body and because sodium and chlorine are associated in the form of common salt (Underwood, 1981). Sodium, potassium and chlorine function in maintaining osmotic pressure, regulating acid-base equilibrium and controlling water metabolism in the body tissues. They control the passage of nutrients into the cells and waste products out (Loosli, 1978; Underwood, 1981).

Sodium occurs largely in extracellular fluids and it makes up 93% of the bases of blood serum. It is not present in blood cells, whereas potassium occurs in the red blood cell. Chlorine is found within the cells and in the body fluids (Loosli, 1978; Underwood, 1981).

Sodium and chlorine are essential dietary elements. Animals need a regular supply in the diet because there is limited body storage capacity

(Loosli, 1978). The first sign of sodium deficiency in cows is a pica for salt, manifested by eating wood, soil or sweat of other animals (Underwood, 1981). However, when the animal is deprived of salt (NaCl), it is able to conserve the limited body reserves by largely eliminating urinary losses. Even after severe deficiency, neither blood levels of NaCl nor the amounts secreted in milk decrease (Loosli, 1978). However, if supplementary salt is provided before the state of collapse is reached, a dramatic recovery in appetite, appearance, weight and milk production occurs (Underwood, 1981).

As previously stated, sodium occurs primarily in the extracellular fluids, playing an important role in the function of regulating neutrality in the blood, constituting about .2% of the body weight (Maynard et al., 1979). However, sodium not only functions in the regulation of the balance of body fluids, it also plays an important role in nerve impulse transmission, in the maintenance of heart function, and in carbohydrate and protein metabolism (Fenner, 1980). Recently, sodium bicarbonate has received attention as a buffer in studies on intake, performance and its effects on digestion (Erdman et al., 1982; Haaland and Tyrell, 1982).

Potassium is the third most abundant element in the animal body. In contrast to sodium, potassium is present primarily inside the cells (Thompson, 1978b). It is absorbed mainly in the upper small intestine, although some absorption also occurs in the lower small intestine and large intestine (Church and Pond, 1974). According to Greene et al. (1983), the primary site of potassium absorption is the small intestine; nevertheless, with high levels of potassium in the diet, the preintestinal region is also an important site of absorption.

The main functions of potassium in the animal are maintenance of acid-base balance, osmotic pressure, enzyme reactions for phosphorylation of creatine, pyruvate kinase activity, cellular uptake of amino acids, protein synthesis, carbohydrate metabolism, and maintenance of normal heart and kidney tissues (Church and Pond, 1974).

The clinical and biochemical manifestations of potassium deficiency in beef cattle are not as well documented as they are for sodium, perhaps due to the high supplies of this mineral in most forages (Underwood, 1981). Precise data on the requirements of potassium are not available; however, Thompson (1972) recommended .6 to .8% potassium in the dry matter for growing beef cattle and .8 to 1% potassium in the dry matter for lactating animals. Similar values are reported by McDowell et al. (1983) in table 9.

On the other hand, high levels of dietary potassium are toxic to ruminant animals. Excessive intake appears to interfere with the absorption and utilization of magnesium (NRC, 1980). According to Greene et al. (1983), magnesium absorption in steers decreased linearly with increasing levels of dietary potassium.

Chloride functions mainly in ensuring proper fluid-electrolyte balance (NRC, 1980). It has been known for many years that HCl is present in gastric juice and that chlorine is critical for maintaining acid-base equilibrium in body fluids; thus, it is considered an essential dietary element. The experimental rat is one of the animals in which a deficiency has been produced. Chlorine deficiency has not been reported in ruminants, even though many forages are very low in this element (Loosli, 1978). However, Neathery et al. (1981) reported that chloride deficiency signs were produced in young Holstein calves with a low chloride diet (.063% Cl). General clinical signs included anorexia, weight loss and mild polyuria.

A craving for salt is the earliest and most obvious criterion for sodium deficiency in the animal (Underwood, 1981). It is now recognized that sodium deficiency can greatly decrease productivity of beef cattle. The deficiency is characterized by a decline in sodium concentration in saliva and urine and an increase in potassium levels in these fluids (Loosli, 1978). This may be explained by the fact that urinary excretion is the most important mechanism of sodium elimination by ruminants (Pearson and Wolsak, 1982).

The NRC (1976) suggested the minimum sodium requirements for grazing beef cattle to be close to .06% of the dry matter in the diet (table 11). Little is known of the chlorine requirements for growth or milk production (Underwood, 1981); however, the author suggested that they would be substantially higher than the .15% sodium for lactating dairy cattle, since cow milk contains more than double the chlorine in comparison to sodium. Maximum tolerance levels of dietary salt for cattle were set at 9% (Meyer et al., 1955). The NRC (1980) indicated that the major factor influencing salt toxicosis in animals is the availability of drinking water and the presence of an adequate supply.

Assessment of sodium and potassium status

Due to large reserves of mobilizable body sodium, blood plasma sodium is not a sensitive indicator of sodium status (Kemp, 1964). Similarly, according to Underwood (1981), the signs of sodium deficiency occur without a significant decline in plasma sodium concentration until the animal is "in extremus". In addition, urinary sodium declines rapidly to extremely low values and fecal sodium is reduced. With a sodium-deficient diet, sodium levels in saliva decline and potassium levels in parotid saliva increase in ruminants, providing a large reduction in the sodium-to-potassium ratio, to less than 1:1 (Underwood, 1981).

Conrad (1978) indicated that the sodium-to-potassium ratio in saliva was the most sensitive and reliable indication of sodium status in ruminants. Normal values in saliva are 3.3 g/liter of sodium and .3 g/liter of potassium. Values of less than 1 g/liter sodium and more than 2.5 g/liter potassium are signs of deficiency (CMN, 1973). Furthermore, Conrad (1978) summarized that for the assessment of sodium and potassium, saliva is the most sensitive; rumen liquor shows marked diurnal fluctuations, urine sodium varies widely, fecal excretion of sodium is variable, and milk sodium is only slightly decreased with low sodium intake. However, Pradhan and Hemken (1968) suggested that in the case of potassium deficiency, depressed plasma potassium is characteristic. These results were similar to those found by Lentz et al. (1976), in which plasma levels of potassium and immunoreactive insulin were elevated by intravenous infusion of potassium chloride in calves and intraruminal infusion of potassium in cows.

Iron

Although the body contains only about .004% iron, this element plays a central role in life processes. Iron is essential to every form of life from plants to man. In animals, iron is a constituent of hemoglobin, myoglobin, cytochromes and many other enzymes (Maynard et al., 1979; NRC, 1980). It occurs as an iron-porphyrin nucleus, known as heme, not only in hemoglobin but also in proteins which are components of cytochrome c, peroxidases, catalases and other enzymes. Body iron consists of two fractions. One is essential body iron present as hemoglobin, myoglobin and certain cellular enzymes; the other fraction is found as ferritin and hemosiderin, constituting a mobilizable iron reserve (Finch, 1976).

Most iron absorption takes place in the small intestine. Ferrous iron enters blood plasma as quickly as it is oxidized to the ferric state (NRC, 1980). This form is then complexed with a specific β1-globulin (transferrin), and it is transported to different parts of the body as required for use or storage (NRC, 1980). However, recent studies in humans indicate that iron fortification of infant food supplements, in relation to the amount of iron absorbed, is relatively poor (Morck and Austic, 1981). Furthermore, high levels of dietary phosphorus or phytate in ruminants interfere with the absorption of iron, apparently through competition for protein-binding sites in the intestinal mucosa (Underwood, 1971).

As previously stated, the great majority of iron in the body is in hemoglobin, located in the erythrocytes. Hemoglobin makes up approximately one-third of the red blood cell (Miller, 1981). Myoglobin contains less iron than hemoglobin, playing an important role in the muscle (Maynard et al., 1979). In addition, ferritin is the main iron storage compound of the body, and its concentration in the tissues together with that of hemosiderin reflects the iron status of the animal (Underwood, 1981).

Iron deficiency is of limited practical significance in farm animals, with the exception of sucking piglets (Underwood, 1981). There are few reports of iron deficiency in grazing animals. However, in conditions involving severe blood loss, such as in parasitic infestation, which could induce changes in iron metabolism, a secondary iron deficiency anemia could result (McDowell et al., 1978; Underwood, 1981). Therefore, McDowell et al. (1983) proposed that iron supplementation is most warranted for grazing livestock when forages contain less than 100 ppm iron and/or insects or parasites are causing a substantial blood loss.

Iron deficiency results in hypochromic, microcytic anemia, with low serum iron, increased total serum iron binding capacity and a decreased transferrin saturation (Conrad, 1978). The suggested iron requirement for beef cattle as shown in table 9 is about 30 ppm (NRC, 1976), and based on available information, the maximum tolerable level of dietary iron in cattle is 1000 ppm (NRC, 1980).

Liver iron

Ferritin is the main iron storage compound, and its concentration together with that of hemosiderin in the tissues reflects the iron status of the animal (Underwood, 1981).

The liver is the central point of mineral metabolism in the animal body and is a useful organ for the estimation of iron and many other micromineral statuses of animals (Boyazoglu et al., 1972). Low hemoglobin and hematocrit values are not sensitive indicators of early iron deficiency because they do not occur until iron storage is severely depleted (Conrad, 1978; McDowell et al., 1978). Thus, their use is often limited to diagnosis and confirmation of iron deficiency (Miller and Stake, 1974).

The normal values for iron in liver vary according to different researchers. Hartley et al. (1959) gave a range of 180 to 340 ppm, dry weight basis; Cunha et al. (1964) indicated values from 200 to 300 ppm; and Ammerman (1970) found liver levels of 100 to 300 ppm iron in Florida cattle with adequate copper nutrition. Lebdosoekojo (1977) found that young bulls with access to mineral supplementation on native pastures of the Eastern Plains of Colombia had liver iron levels of 351 ppm (dry matter). Vargas (1982) found liver iron values of more than 468 ppm in cattle in the llanos of Colombia. Similarly, in Malawi, Mtimuni (1982) reported liver iron values greater than 200 ppm in cattle and concluded that liver iron significantly decreased in the rainy season due to increased animal growth during the same season. In addition, McDowell et al. (1980) summarized that less than 180 ppm of liver iron could be considered a low to critical level. Nevertheless, the differences in normal values of liver iron in cattle are due to the interrelationship of this element with other micronutrients; as was described by Rosa (1980), high dietary zinc antagonizes the effect of iron, reducing iron storage.

Copper, Molybdenum and Sulfur

There are advantages in considering copper, molybdenum and sulfur together due to their nutritional interrelationship and their profound metabolic interactions (Underwood, 1981).

Copper is essential for growth and for the prevention of a wide range of clinical and pathological disorders in all animal species (Underwood, 1981). The importance of copper in mammalian nutrition has been recognized; copper as well as iron is required to prevent anemia in animals fed exclusively on milk (O'Dell, 1976). A number of metalloenzymes containing copper were identified in the cells and tissues, including ascorbic acid oxidase, lysyl oxidase, cytochrome oxidase, ceruloplasmin and superoxide dismutase (NRC, 1980; Underwood, 1981). Furthermore, the failure of injected iron to correct anemia in animals indicates that copper is essential for the utilization of iron in hemoglobin synthesis. It has been found that copper plays an important role in hemoglobin synthesis as well as in red-cell maturation (Maynard et al., 1979).

In many areas of the world, copper deficiency occurs naturally in grazing cattle; however, in some areas it occurs as a dual deficiency of copper and cobalt (Underwood, 1981). Most of the copper deficiencies occuring naturally in livestock are related to the presence of dietary factors in the affected area which will interfere with copper utilization by the animal (Underwood, 1981). Such is the case in the well known three-way interaction between copper, molybdenum and sulfur, in which an excess of molybdenum may cause a conditioned copper deficiency (Maynard et al., 1979).

Copper absorption is limited in the stomach and for most species appears to take place in the duodenum and jejunum (O'Dell, 1976; NRC, 1980). Absorption is affected by other chemical forms of ingested copper and by other elements such as zinc, cadmium, mercury and silver (O'Dell, 1976), as well as by the concentration of dietary protein, which affects copper solubility in the stomach of ruminants (Ivan and Veira, 1981). Furthermore, molybdenum plus sulfur reduce copper retention, at least in ruminants, since there is evidence that copper and molybdenum form an insoluble compound called "Lindgrenite" which may not be readily absorbed (O'Dell, 1976).

As the copper available to an animal becomes insufficient for all the metabolic processes, manifestations of deficiency occur. Copper deficiency includes a wide variety of clinical signs differing substantially from area to area; the lowering of blood and liver copper is a frequent finding, although anemia is not (Maynard et al., 1979). Nevertheless, anemia is a common expression of severe copper deficiency (Underwood, 1981). Copper is a constituent of ceruloplasmin, the copper-containing metalloenzyme which is necessary for the formation of transferrin, and transferrin, in turn, is critical in mobilizing iron for hemoglobin synthesis (Underwood, 1981). One of the most dramatic signs of copper deficiency is the massive internal hemorrhages which result from angiorrhexis or spontaneous rupture of a major vessel such as the aorta or the heart (O'Dell, 1976). One of the biochemical lesions in bones of copper-deficient animals is a reduction in the activity of lysyl oxidase, producing a decrease in the stability and strength of bone collagen. In some areas, a low incidence of bone fractures occur in cattle grazing copper-deficient pastures (Underwood, 1981) or in the case in which molybdenum is applied to pastures at commercial rates (Langlands et al., 1981); however, no explanation was reported.

Camargo et al. (1982) reported the incidence of "cara inchada" (swollen face). This is a periodontal inflammatory process, with loosening and shedding of the teeth, and swelling of the maxillary and mandibular bones. The author suggested that this condition is related to low levels of copper and, possibly, zinc in pastures, and that a copper-molybdenum-sulfur interrelationship is involved. The condition can be controlled by appropriate trace element supplementation.

Achromotrichia is usually the earliest clinical sign of copper deficiency in cattle and is characterized by greying of the hair (Underwood, 1981). Also, low fertility in cattle grazing copper-deficient pastures was reported by Ruksan et al. (1982). Similarly, Underwood (1981) suggested that copper deficiency is associated with delayed or depressed estrus.

The major biochemical role of molybdenum in animals is believed to be in the formation and activity of xanthine oxidase, a molybdenum-containing metalloprotein essential to the metabolic degradation of purines to uric acid (De Renzo et al., 1953, cited by NRC, 1980). Dietary molybdenum, with the exception of molybdenite, is absorbed in the gastrointestinal tract, but the rates of absorption, retention and excretion of molybdenum are inversely related to the level of dietary inorganic sulfate (NRC, 1980).

Miltimore and Mason (1971) reported that a critical copper-to-molybdenum ratio in feed is considered to be 2:1, and forage samples with ratios below 2 would be expected to cause conditioned copper deficiency in cattle. It is difficult to clearly establish copper requirements for ruminants because there are several factors present in the diet interfering with copper metabolism (Coelho, 1978). Maynard et al. (1979) suggested that 5 to 8 ppm copper in pasture dry matter is sufficient for adequate maintenance of animals. According to the NRC (1976), the recommended requirement for growing and fattening cattle is about 4 ppm (table 11). On the other hand, Miller et al. (1972) considered that for the various existing interactions, the molybdenum requirement has not been adequately determined; nevertheless, the NRC (1980) indicated that manifestation of molybdenum toxicosis in cattle includes diarrhea, anorexia, achromotrichia and posterior weakness when natural forages contained more than 25 ppm molybdenum. The NRC (1980) indicated that the molybdenum tolerance for growing cattle is around 6.2 ppm, and when there is impaired bone development in cattle, molybdenum levels are in the range of 5 to 10 ppm.

Blood plasma copper

The concentration of copper is reported interchangeably in serum and plasma. However, copper in serum has been found to be higher (7%) than in plasma from the same blood sample (Owen, 1982). The criteria most widely used for copper deficiency are the concentrations of copper in liver and blood. Although whole blood or plasma concentrations reflect the dietary copper status, the normal range is wide (Underwood, 1981). Furthermore, Underwood (1981) indicated that the normal range for cattle may be 0.6 to 1.5 µg/ml, with a high proportion of values lying between 0.8 and 1.2 µg/ml. McDowell et al. (1983) reported that serum copper lower than 0.65 µg/ml could be considered a critical level for cattle (table 9). Similarly, Underwood (1981) accepted that whole blood or plasma copper values below 0.5 µg/ml are indicative of deficiency in cattle; however, it has been suggested that this critical level could be too high (Smith and Coup, 1973).

In cattle, the copper status of plasma can be readily determined from serum ceruloplasmin activity. Ceruloplasmin (ferroxidase), synthesized in the liver, contains eight copper atoms per mole (Conrad, 1978). Furthermore, the author stated that plasma copper mainly exists as ceruloplasmin, and high correlations between serum copper and ceruloplasmin activity were found.

Owen (1982) enumerated factors which could affect the copper in serum or plasma, such as species, sex, stage of growth and physiological status of the animal. He reported that plasma copper in the pregnant cow begins rising during the third month, but not until the last trimester does red blood cell copper rise (Bingley and Dufty, 1973, cited by Owen, 1982).

Liver copper and molybdenum

"When one considers the concentration of copper in any organ, the rate of uptake and release of the metal and the organic forms of the intracellular metal, it is quickly apparent that each organ is unique in its handling of copper" (Owen, 1982).

The liver is the central organ in copper metabolism; it removes ionic copper from blood, excretes a portion into the bile, synthesizes ceruloplasmin with another portion, and the remainder could be stored as copper in the liver (Owen, 1982). Since the liver is the main storage organ of body copper, then liver copper concentrations would be expected to provide a useful index of the status of copper in the animal (Underwood, 1981). If the liver is copper-deficient, a small amount of copper is excreted via the bile, and the majority emerges in the blood as ceruloplasmin; in contrast, if the liver is overloaded with copper, further copper is stored in the liver, with about the same amounts disposed of in the bile and in blood ceruloplasmin (Owen, 1982).

Liver copper concentrations reflect the dietary status, but they could be influenced by the dietary proportions of molybdenum and sulfur (Mills et al., 1976). On a dry weight basis, a wide range of values have been reported for the copper content of liver: 33 to 38 ppm (Bingley and Dufty, 1972), 70 ppm (Linder and Munro, 1973), 20 to 25 ppm (Underwood, 1981). However, the CMN (1973) reported that the approximate normal copper level in cattle is 200 ppm on a dry matter basis; levels below 50 ppm indicate a deficiency and below 10 ppm, severe deficiency. Similarly, McDowell et al. (1983) suggested critical levels of copper between 25 and 75 ppm (table 9).

As previously stated, liver copper concentrations are influenced by various dietary factors. Rosa (1980) studied the interrelationship between copper, zinc and iron in sheep and found that high dietary zinc and iron increased liver copper concentrations in the presence of low levels of dietary copper. Langlands et al. (1981) studied the relationship of changes in hepatic copper storage in sheep grazing on pastures fertilized with sulfur and molybdenum and found a decrease in liver copper storage with increased molybdenum fertilization; however, the results indicated that copper deficiency in sheep is unlikely when molybdenum is applied at commercial rates.

When Vargas (1982) investigated the mineral status of cattle in the Eastern Plains of Colombia, he concluded that low levels of copper and zinc in liver could be factors aggravating the "secadera" condition (a wasting disease) in the area. In addition, high levels of molybdenum could have been producing a secondary copper deficiency.

Toxicosis is the major concern in molybdenum nutrition (McDowell et al., 1983). Suttle (1980) suggested that values of less than 10 ppm dietary molybdenum in ruminants affect copper metabolism. According to Ammerman and Miller (1975), levels of more than 40 mg/day of molybdenum could alter hepatic copper levels. McDowell et al. (1983) (table 9) indicated that above 4 ppm liver molybdenum could be suggestive of an excess of this element.

Zinc and Manganese

Over forty years ago, zinc was found to be essential for rats and mice (Sandstead, 1976). The zinc content of the body is only approximately 3 mg percent. The highest concentrations are found in epidermal tissues, such as skin, hair and wool; traces also occur in bones, muscle, blood and various organs (Maynard et al., 1979).

Zinc appears to participate in metabolism in at least two ways: as an essential component of certain enzymes, and through its presence on the structural configuration of other organic ligands (Sandstead, 1976). Some of the enzymes containing zinc are the alcohol dehydrogenases, alkaline phosphatases, carboxypeptidases, RNA and DNA polymerases, and several others (Underwood, 1981). The metal is located at the active site of the zinc metalloenzymes and is involved in the catalytic process (NRC, 1980). In addition, some nonenzyme ligands with which zinc forms complexes include albumin, which loosely binds around 66% of plasma zinc, and α 2-macroglobulin glycoprotein in plasma, which firmly binds about 30% plasma zinc (Sandstead, 1976).

Zinc is absorbed in the intestinal tract, and the primary route of excretion is feces. In addition to unabsorbed zinc, small amounts of fecal zinc come from pancreatic secretion, bile, epithelial cells and zinc secreted directly into the gut (NRC, 1980). Recently, Johnson and Evans (1982) studied zinc uptake and concluded that the ileum has the largest population of Paneth cells; the high zinc uptake observed in this segment of the small intestine suggested a role for Paneth cells in zinc homeostasis.

Characteristics of deficiency include growth retardation, delayed sexual maturation, alopecia, parakeratosis, skin lesions, hyperkeratinization of the esophagus, skeletal abnormalities and impaired reproduction (NRC, 1980). Clinical signs of zinc deficiency in cattle under natural grazing conditions respond to zinc therapy, as was indicated by Underwood (1981).

Until recent years, it was thought that field cases of zinc deficiency in ruminants were unlikely, but studies suggest that borderline deficiencies may be more common than realized (Maynard et al., 1979). However, Conrad (1978) reported that zinc deficiency in grazing ruminants is not a major area problem like copper, cobalt and selenium. Furthermore, McDowell et al. (1978) stated that in recent years, deficiency in grazing animals has been reported in several countries when the zinc content in the diet was less than 40 ppm. Such is the case in northern Mato Grosso, Brazil, where Sousa (1978) found forage zinc levels ranging from 19 to 39 ppm in the dry matter. Later, Camargo et al. (1982) found forage values between 16 and 34 ppm in dry matter.

The dietary requirement of zinc for beef cattle appears to be between 20 and 30 ppm on a dry matter basis. Deficiency signs have been encountered with diets containing less than 3 ppm (NRC, 1976). Animals are quite tolerant to excessive dietary zinc; however, since control of zinc occurred in cattle fed 60 ppm zinc, it would be important to limit zinc levels to no more than 500 ppm (NRC, 1980). Similarly, according to Neathery and Miller (1976), the maximum tolerance of zinc for growing cattle is 500 ppm, and 1000 ppm for mature animals.

Manganese is widely distributed in very low concentrations in the cells and tissues of the animal body. It is necessary for development of bone and adequate maintenance of reproductive processes in both males and females (Underwood, 1981).

The enzymes activated by manganese are numerous and include kinases, hydrolases, transferases and decarboxylases (Vallee and Coleman, 1964, cited by Underwood, 1981). The synthesis of mucopolysaccharides is a specific function of manganese, and it is involved in the metabolism of carbohydrates and lipids.

Manganese is absorbed throughout the intestinal tract. The homeostatic mechanism regulating tissue levels involves the excretion of manganese via the intestine and bile (NRC, 1980). Furthermore, the NRC (1980) suggested that manganese absorption is decreased by feeding isolated soy protein or excess levels of calcium, phosphorus or iron. However, Ivan and Veira (1981) studied the effects of dietary protein on the solubility of manganese in the rumen and abomasum of sheep and showed that there was no effect of dietary protein on the solubility of manganese in the rumen and in the abomasal digesta flowing into the duodenum of the animal.

Manganese deficiency has been produced in every species tested. One of the first deficiency effects reported was skeletal abnormalities (Hurley, 1976). Maynard et al. (1979) showed that manganese deficiency may result in a wide variety of signs, including reduced growth rate, delayed sexual maturity, degeneration of germinal epithelium, irregular ovulation, resorption of the fetus, ataxia and skeletal deformities.

According to Underwood (1981), the minimum requirements of dietary manganese for ruminants are not precisely known. In cattle, manganese requirements are substantially higher for reproduction and birth of normal calves than for growth (NRC, 1978). The manganese requirement for growing cattle is low, usually from 1 to 10 ppm of dietary dry matter. However, with high levels of dietary calcium and/or phosphorus, the manganese requirement is apparently somewhat elevated (NRC, 1978).

In general, adverse health effects have not occurred in most species with dietary concentrations of 1000 ppm manganese or less, although some metabolic alterations have been observed. Since manganese and iron are mutually antagonistic with a low iron intake, animals are more sensitive to manganese toxicity while excess iron will have a protective effect. However, homeostatic mechanisms maintain most tissue manganese concentrations within fairly narrow limits by excreting excess manganese via small intestine or bile.

Blood plasma zinc

Zinc concentration in serum or plasma is currently the most widely used criterion of zinc status. Although affected by factors other than zinc status, it is not sensitive to marginal zinc deficiencies (Apgar and Welch, 1982). Similarly, Conrad (1978) stated that zinc levels in plasma and serum can be markedly reduced by a severe zinc deficiency, but their practical diagnostic value is limited.

Iyengar (1982), in a summary of the problems in trace element analysis in biological systems, indicated that plasma zinc is affected by genetic predisposition, age, circadian rhythm, posture and stress of the animal during sampling, and contamination. The author also emphasized that only a few studies have reported significant changes in zinc concentration of serum, depending upon time of day. However, there is no unified picture concerning the time of day at which peak concentrations are reached, suggesting that more intricate factors are involved in controlling its level.

Apgar and Welch (1982) stated that other parameters have been suggested for determining zinc status, but so far none have been shown to be of greater value than plasma or serum zinc concentration. According to the CMN (1973), zinc concentration in plasma of healthy cows is .6 to 1.4 μg/ml, indicating a normal zinc status. However, Conrad (1978) indicated that serum or plasma zinc is rapidly and markedly reduced with severely deficient diets, although they are not greatly influenced by marginally deficient diets. Mills et al. (1967) indicated that 10 to 14 ppm of zinc in a semipurified diet were sufficient to maintain normal plasma levels between .8 and 1.2 μg/ml in calves.

Liver zinc and manganese

Underwood (1962) suggested that liver zinc values above 125 ppm should be considered as the normal value for cattle. Meanwhile, values from 84 to 132 ppm in cattle liver, expressed as dry matter basis, were considered normal by Miller and Miller (1962).

Factors which reduce zinc absorption in the gastro-intestinal tract have also been found to reduce zinc concentration in the liver, such as phytic acid, calcium, magnesium, phosphorus, copper and chelating agents such as EDTA (Miller, 1975). Therefore, a number of researchers believe that liver zinc is not a good indicator of zinc status (Watson et al., 1973).

According to the CMN (1973), there is as yet no practical criterion for assessing the manganese status of animals; however, liver concentration seems the most promising. The normal level of manganese in cattle liver is 8 to 10 ppm on a dry matter basis, according to Underwood (1977). Egan (1975) considered liver manganese values below 6 ppm as indicating deficiency. Similarly, McDowell et al. (1978) concluded that manganese deficiency can best be detected when there is a combination of less than 6 ppm of manganese in the liver and less than 20 to 40 ppm in the diet. In addition, a mild manganese deficiency is reflected in reduced reproductive performance.

Several researchers have noted only small changes in tissue manganese levels with an increase in dietary manganese (Thomas, 1970). According to Carter et al. (1974), it appears that liver manganese changes readily up to a certain level (about double normal) and then resists further changes. Watson et al. (1973) indicated increased liver manganese concentration in animals from 10 to 44 ppm as the dietary manganese increased from 30 to 4030 ppm.

Cobalt

The first evidence of cobalt's essential role developed as a result of long-term studies of certain peculiar wasting diseases of grazing animals, known by various names in different areas of the world (Maynard et al., 1979). Australian reserachers called it "coast disease" and "wasting disease" while in New Zealand, it was known as "bush-sickness" (Underwood, 1981). Similarly, in Florida, the condition was called "salt sick" and was first reported by Maxwell in 1888 (Becker et al., 1965).

The mystery involving the role of cobalt was solved as a result of the discovery of vitamin B_{12}, an antianemic and growth factor which was found to contain cobalt in its molecule (Maynard et al., 1979). Cobalt per se is a dietary essential element for ruminants, since cobalt is incorporated into vitamin B_{12} by gastrointestinal microbes (NRC, 1980). Thus, the long observed cobalt deficiency problem in ruminants is actually a vitamin B_{12} deficiency (Maynard et al., 1979).

Cobalt is not absorbed to a high degree by ruminants. The element is used by microorganisms to synthesize vitamin B_{12} in the rumen (NRC, 1980). However, when cobalt is injected, it accumulates in the liver. Furthermore, it has been shown that cobalt-deficient ruminants have a very low vitamin B_{12} content in blood compared to normal animals. Injecting the vitamin alleviates cobalt deficiency symptoms, whereas injecting the mineral itself does not (Maynard et al., 1979). Similar results were observed by Judson et al. (1982) who studied the effect of oral cobalt pellet therapy and subcutaneous injection of vitamin B_{12} on liveweight and blood constituents of Hereford calves in south Australia. The calves were raised on coastal soil which is known to produce cobalt deficiency.

In addition to the importance of cobalt as a component in vitamin B_{12}, it is believed to have other functions in the body as an activating ion in certain enzymes (Houser et al., 1978). Such is the case in propionate metabolism at the point at which methylmalonyl-CoA is converted to succinyl-CoA, a reaction catalyzed by methylmalonyl-CoA isomerase, a vitamin B_{12}-requiring enzyme. This reaction has been shown to be absent in cobalt-deficient ruminants (Marston et al., 1961, cited by Underwood, 1981).

For all practical purposes, cobalt deficiency signs in cattle are similar to those of general malnutrition (Maynard et al., 1979). The animals become listless, with lack of appetite, rough hair coat, thickening of the skin, anemia and eventually death occurs (Underwood, 1981). The anemia produced is of the normocytic, normochromic type, thus differing from that occurring in iron or copper deficiency (Maynard et al., 1979).

The minimum cobalt requirement for dairy cattle is around .1 ppm of the dry ration (Ammerman, 1970). Similarly, Houser et al. (1978) reported that grass dry matter from healthy areas contained an average of .1 ppm cobalt, while deficient areas had .004 to .07 ppm; as little as .1 ppm has restored sick animals to health. The NRC (1980) suggested that the supplemental sources of cobalt can be administered by incorporating the element into mineral mixes, by drenching with cobalt solutions, or by the use of cobalt "bullets" composed of cobalt oxide and fine particles of iron.

Cobalt is known to interact with iron, copper, selenium and molybdenum. Ammerman (1981) found that cobalt-deficient animals are more susceptible to selenium toxicity than animals fed adequate amounts of cobalt. Thus, the cobalt-selenium relationship may involve vitamin B_{12} in the metabolism of dimethyl selenide.

Although cobalt deficiency in ruminants is more frequent than cobalt toxicosis, the NRC (1980) reported that cattle tolerated cobalt at a level of 300 times the requirements.

Liver cobalt

There are a number of biological tissues found helpful in diagnosing the cobalt status of grazing animals (Conrad, 1978). Cobalt concentration in cattle liver is sufficiently responsive to changes in cobalt intake to have some value in the diagnosis of cobalt deficiency (Conrad, 1978; Underwood, 1981). Although Houser et al. (1978) stated that cobalt is widely distributed throughout the body, there is no excessive accumulating tissue, yet the highest concentrations usually occur in the liver and kidney. Ammerman (1981) reported that a decrease in ruminant liver cobalt storage and vitamin B_{12} are indicative of a dietary cobalt deficiency.

McDowell et al. (1983) suggested that liver cobalt levels between .05-.07 ppm (dry basis) are deficient, while levels above that are normal for healthy animals (table 9). However, Conrad (1978) reported that most studies indicated that values of less than .1 ppm liver cobalt could be considered deficient.

Underwood (1981) believed that because blood cobalt values are so variable, they are not good indicators of cobalt status. Therefore, the best cobalt deficiency verification method is to provide a cobalt salt supplement and then measure positive production responses (Houser et al., 1978). McPherson (1982) studied plasma vitamin B_{12} concentrations in cattle and concluded that current minimum standards of normality for vitamin B_{12} status in cattle may have to be revised and/or more specific assay methods need to be developed.

Recently, Peducassé (1982) in Bolivia, Jerez (1982) in the Dominican Republic, Mtimuni (1982) in Malawi and Vargas (1982) in Colombia investigated the mineral status of grazing cattle and reported no deficiency in liver cobalt of the samples analyzed, with values greater than .05 ppm cited as a critical level of cobalt (table 9).

Selenium

The importance of selenium to nutrition was recognized in 1957, when it was shown to prevent dietary necrosis in rats (Underwood, 1981). Subsequently, selenium deficiency has been found in several animal species, including cattle, sheep, rats, poultry and primates (Hidiroglou, 1980; Conrad et al., 1982). Selenium has been considered an essential element, since the first studies demonstrated its importance as an effective component of "factor 3" in preventing nutritional muscular dystrophy in calves. However, selenium has had a profound and lengthy history of toxicity (Ammerman et al., 1978).

One of the biochemical functions of selenium in higher animals was defined by Rotruck et al. (1973), who discovered that selenium was a constituent of the enzyme glutathione peroxidase. This enzyme destroys lipid peroxides and therefore functions in protecting cell membranes against peroxidative damage (NRC, 1980). A metabolic interrelationship between selenium, vitamin E and sulfur-containing amino acids exists at the cellular level. Glutathione peroxidase uses glutathione, a tripeptide-containing sulfur amino acid, to reduce hydrogen peroxide and organic hydroperoxides to less harmful products (Hidiroglou, 1980). Vitamin E reacts or functions as a chain-breaking antioxidant, thereby neutralizing free radicals and preventing peroxidation of lipids within the membranes.

Peroxidation of lipids can destroy the structural integrity of cells and cause metabolic derangements (Maynard et al., 1979).

Selenium absorption from the gastrointestinal tract varies with the chemical form and amount ingested (NRC, 1980); however, the metabolism of absorbed selenium appears to be similar for ruminants and monogastric animals (Ammerman et al., 1978). Radioactive studies with different levels of radioselenium indicated that the duodenum is the main site of absorption, with no absorption from the rumen and abomasum of ruminant animals (NRC, 1980). A positive response has been obtained in grazing ruminants with oral administration of selenium as either sodium selenate or sodium selenite (Underwood, 1981). Furthermore, selenate was considered preferable, since selenite is more readily reduced to less available elemental selenium which could form insoluble compounds with other metals (Ammerman et al., 1978).

Selenium is found firmly attached to all types of protein following absorption. In animal metabolism, selenium is usually related with sulfur-containing components, and it has been suggested that both selenium and sulfur may utilize the same metabolic pathway (McConnell et al., 1974).

Muscular dystrophy in young ruminants and reproductive failure in adults are often consequences of selenium deficiency (Conrad et al., 1982). Furthermore, McDowell et al. (1983) stated that in grazing animals, different selenium deficiency syndromes have been described such as white muscle disease in calves, unthriftiness, infertility and retained placenta. Similarly, Conrad et al. (1982), at the Ohio Agricultural Research and Development Center, demonstrated its essentiality for the prevention of post-parturient reproduction problems and discovered that a shortage of dietary selenium was an important factor in herds having a high incidence of retained placenta.

Manifestations of selenium and vitamin E deficiencies in ruminants reflect their similar, yet independent, roles. Although the effectiveness of vitamin E in protecting against the myopathies induced by high intakes of polyunsaturated fatty acids has been demonstrated, the possibility that the prophylactic effect of vitamin E is modified by the selenium status of animals has not been examined (ARC, 1980).

The ARC (1980) suggested that when the selenium content of the diet is .03 ppm in the dry matter or less, the incidence of disorders is increased, and contents of less than .03 ppm are therefore considered inadequate. In addition, the same committee indicated that monitoring the selenium status of animals by assay of the selenium-containing enzyme, glutathione peroxidase, may in the near future reflect an expression of selenium requirements with greater precision. The NRC (1980) reported greater dietary requirements for selenium, ranging from .1 to .3 ppm in the dry matter.

Signs of toxicity have been observed in animals consuming more than 5 ppm of selenium in short-term studies. However, 2 ppm of the element have produced no unequivocally toxic signs, and this dietary concentration is suggested as a maximum tolerable level for all species (NRC, 1980).

McDowell et al. (1983) stated that locating seleniferous areas and mapping them in sufficient detail is essential. Nevertheless, large variations in selenium content of different plant species growing on the same soil have been reported by a number of researchers. Acute selenium poisoning is most often associated with consumption of selenium accumulator plants such as Astrogalus racemous, which may contain from 100 to 9000 ppm of selenium (Ammerman et al., 1978).

Blood plasma selenium

The most widely used assessment of selenium status is blood selenium, since low levels are always found in selenium-deficient conditions. Hidiroglou (1980) found a direct relationship between blood glutathione peroxidase activity and blood selenium concentration. However, Conrad (1978) reported that kidney cortex and liver are the most sensitive indicators of the selenium status of the animal, and selenium concentrations in these organs can provide valuable diagnostic criteria.

Thompson and Duncan (1982) reported that the activities of the enzyme glutathione peroxidase in whole blood and erythrocytes have been used as a measure of selenium status in humans since the discovery of the association between selenium and glutathione peroxidase. With new subsequent supplementation studies, the authors concluded that the method continues to be a satisfactory way to determine selenium status.

According to McDowell et al. (1983), the critical level of serum selenium for cattle is less than .03 µg/ml. Similarly, the literature reported values between .04 and .08 µg/ml as a normal concentration of selenium in serum of grazing animals.

Liver selenium

As previously stated, Conrad (1978) indicated that the kidney cortex and the liver are the most sensitive indicators of the selenium status of the animal. Furthermore, he suggested that concentrations greater than 1 ppm selenium in the kidney cortex and .1 ppm in the liver are considered normal. However, recently McDowell et al. (1983) stated that the critical level for selenium is .25 ppm on a dry matter basis, according to studies by Andrews et al. (1968, cited by Underwood, 1971).

Although selenium concentration in plasma and liver provides adequate information on dietary selenium intake in cattle, erythrocyte glutathione peroxidase activity could be an alternative test for the diagnosis of selenium deficiency as was reported by Thompson and Duncan (1982).

Physiological Status as a Factor Affecting Mineral Requirements

"Minimum mineral intakes must be sufficient to ensure the long term maintenance of the mineral reserves of the body tissues and the amounts of those minerals in the edible products of the animal" (Underwood, 1981).

Mineral requirements are affected by species, age, physiological status (growth, lactation, etc.), levels of various dietary components, and by the criteria of adequacy employed (NRC, 1980; Underwood, 1981). Furthermore, factors which greatly reduce forage intake, such as low protein content and increased maturity, lignification and stem-to-leaf ratios, likewise reduce the total minerals consumed (Underwood, 1981).

When considering the mineral requirements for production, depending on the physiological status, it should be realized that requiremements, in terms of the minimum adequate levels in the diet, do not necessarily rise in proportion to increased productivity of the animal despite the fact that absolute daily intakes of the minerals must rise in such proportion to meet the increasing amounts in the products formed (Underwood, 1966).

The effects of the diet on the composition of milk vary greatly for different minerals. Dietary deficiency of calcium, phosphorus, sodium and iron are reflected in a diminished yield of milk but not in the concentrations of these minerals in the milk that is secreted (Underwood, 1981).

The calcium concentration of the body would be expected to increase in early life due to bone growth and mineralization, and then decline as the deposition of fat increases (ARC, 1980). There is evidence of a fall in the concentration of phosphorus in fast-growing animals, leading to a much reduced concentration in cattle as the empty-body weight increases (ARC, 1980).

The ARC (1980) estimated the requirements for growth, pregnancy and lactation, and reported that dietary requirements for calcium depend on the liveweight of the animal and the rate of gain in the case of growing animals. Similarly, there is evidence that certain lactating cows cannot absorb sufficient calcium to meet their requirements for milk production and that calcium intake of dairy cows in the dry period has a bearing on the subsequent incidence of parturient hypocalcemia and milk fever.

In general, the same pattern is found for calcium and phosphorus. As the animal increases body weight, phosphorus requirements (g/day) increase; however, the coefficient of absorption decreases from .78 in growing animals weighing 50 kg to .58 in 500-kg animals. These requirements also increase as the rate of gain increases (ARC, 1980).

CHAPTER III
MATERIALS AND METHODS

Identification and Description of Research

From 1974 to 1983, the Center for Tropical Agriculture and the Department of Animal Science at the University of Florida, with the assistance of a contract from the Agency for International Development, have been working collaboratively with Latin American institutions to promote mineral research in Latin America (McDowell et al., 1982). The mineral research program in Guatemala began early in 1975. The organization in charge of the project during the first three years was the Institute of Nutrition of Central America and Panama, INCAP (McDowell et al., 1982).

The research for the present experiment was conducted at various farms and regions in Guatemala during different seasons in the years 1980 and 1982.

The variety in ecological characteristics, demographic concentration, market proximity, hydrological resources and communication systems are elements which determine the structure of cattle production in different regions of the country. In this way, the cattle industry is distributed among four regions as shown in appendix figure 1 (Departamento de Investigaciones Agropecuarias e Industriales del Banco de Guatemala, 1965).

Soil, forage and animal tissue samples were collected from different farms within a region during each season, rainy and dry. Collections were made at four, four and six farms in the Northeast, Central and Southwest regions, respectively, for each season.

The two seasons were selected based on the pattern of rainfall. The rainy season extends from May to October for most regions in the country, with the exception of the Northeast (May to December). The dry season continues from November to April, once again excepting the Northeast where it extends from February to April. The sampling periods corresponded to the middle of the rainy season (July-August, 1980) and the middle of the dry season (February-March, 1982).

The selection of three regions was based on the variety of geographical areas, combined with a wide range of climates and soil types which have evolved different cattle production purposes and procedures (appendix figure 2).

The number of farms within regions depended more on the cattle population in each region. Four farms were selected for each of the Northeast and Central regions since these two regions have smaller cattle populations than the Southwest region. Six farms were chosen in the Southwest region since this is the most important cattle region in the country, comprising 50% of the total cattle population (Departamento de Investigaciones Agropecuarias e Industralies del Banco de Guatemala, 1965).

The identification and a general description of important parameters in evaluating animal production for each farm within a region appear in appendix tables 22, 23 and 24. This information was provided directly by farm managers during the sample collection period in 1980. Some data were derived from an approximation by the manager in cases where exact information was not available. Other parameters, such as stocking rate and calving percentage, were calculated later from the data submitted in the questionnaire.

Sample Collection

Soil Samples

Three composite soil samples from each farm were collected during the sampling periods for the rainy and dry seasons (July-August, 1980 and February-March, 1982, respectively). A total of 12, 12 and 18 soil samples were gathered for the Northeast, Central and Southwest regions per season, respectively.

Soil and forage samples were collected at the same site (Sousa, 1978). The depth of the soil sample was similar to the length of the majority of the forage root systems (20 cm).

Each of the three composite soil samples for each farm came from 20 to 25 samples. A soil sampling technique described by Bahia (1978) was used. Although soil samples collected during the two seasons did not come from the exact same spot, they came from the same grazing area of the farm.

Soil and forage samples were collected the same day or the day after animal tissue samples were taken. That same day, approximately 500 g composite soil samples were transferred to plastic bottles and were properly identified for further transportation to the United States.

Forage Samples

Six composites of the major species of unfertilized forage samples from each farm were collected during each of the sampling periods. During each season, a total of 24, 24 and 36 forage samples were collected from the Northeast, Central and Southwest regions, respectively.

Forages were collected after careful observation of cattle grazing patterns. In some cases, it was necessary to watch the animals graze in order to obtain a species sample representative of forage actually being consumed by the animal.

Each of the composite forage samples from each farm came from a total of 20 to 25 individual samples of the same forage species predominating and most frequently grazed in different grazing areas of the farm. However, forage samples from the same farm in both seasons did not come from the same spot but came from the same grazing area.

To avoid contamination, plastic gloves and stainless steel scissors were utilized for forage collection. In addition, only the aerial part of the forage was clipped. Samples were collected in a cloth bag for immediate air-drying. After this process, when dry matter was over 87%, the samples were ground in a hammer mill with stainless steel knives at the INCAP facilities in Guatemala. After mixing, a 60 g sample was transferred into a plastic bag and properly identified for further chemical analysis in the Nutrition Laboratory at the University of Florida.

Animal Tissue Samples

Blood plasma, bone and liver samples were collected from beef cattle from each farm in each region. The animals were divided in two classes, pregnant-lactating cows and growing animals (steers).

Lactating cows were selected according to a particular physiological stage. Therefore, to be classified in this class, the cow needed to have a calf present when the samples were collected. Lactating cows ranged from three to ten years of age, and the majority were Zebu-Criollo with variable degrees of crossbreeding depending on the farm in which samples were collected (appendix tables 22, 23 and 24).

Growing animals were selected on the basis of age, which ranged from one to two years. The breed of growing animals in most farms was

Zebu-Criollo, again with variable degrees of crossbreeding depending on farm.

During each sampling period (rainy and dry seasons), animals from the desired classes were selected at random from each farm. Because it was not possible to follow the animals sampled during the rainy season of 1980, other animals were randomly selected in the dry season of 1982.

Animal stress and excitement was avoided or minimized during and prior to tissue sample collection. However, it is known that under field conditions, it is often difficult to avoid stress as was described by Fick et al. (1977), although an attempt was made to minimize it.

In general, farms selected in each region do not fertilize the pastures. In most instances, they applied urea only in the grazing area at very low application rates (appendix tables 22, 23 and 24). Similarly, the majority of animals received common salt as the only mineral supplement, and in relatively small amounts.

Animal tissue sample collection was usually performed during the early morning on each farm, starting with the growing animals and finishing with lactating cows. The remainder of the day or the following day was utilized for soil and forage sample collection. Animal tissue samples were collected in the early morning to minimize stress to the animal and to avoid time-temperature aspects for the sample prior to separating blood plasma.

In general, the handling facilities in the farms were satisfactory, since the majority of farms had enough pens for stress minimization and squeeze chutes for easier sample collection. Under these conditions, the rate of collection of blood, bone and liver samples was approximately four animals per hour, when using at least five persons in the handling facilities.

Blood plasma

Duplicate blood samples were obtained by jugular puncture and were collected in vacutainer tubes. These collection tubes contained the anticoagulant lithium citrate (5 mg/ml blood), following the technique proposed by Fick et al. (1979).

Blood samples were left standing in a cool environment prior to centrifugation. As soon as 12 blood samples were ready (approximately 6 animals, 90 minutes each), the blood samples were centrifuged at 2500 rpm for 15 to 20 mintues at the respective farm. It was necessary to carry a portable generator to each farm, since most of the farms did not have electricity.

Blood plasma samples were collected for each season from 10 lactating cows and 10 growing animals from each farm, with a total of 80, 80 and 120 blood plasma samples for the Northeast, Central and Southwest regions, respectively.

Blood plasma samples were identified and kept frozen after centrifugation until the precipitation of plasma proteins was completed at the Nutrition Laboratory at the University of Florida. Procedures and techniques for blood processing have been proposed by Fick et al. (1979).

Bone biopsy

Two bone biopsy samples from lactating cows were collected at each farm for a total of 8, 8 and 12 samples for the Northeast, Central and Southwest regions, respectively. Bone biopsy samples were taken as described by Little (1972), with some modifications in the technique. A single sample was removed from the right side of the animal at the 12th rib. The most convenient location on the rib was approximately 15 cm ventral to the line of the lumbar transverse (backbone). The same vertical incision, approximately 4 cm in length, made for the liver biopsy was used for the bone biopsy.

The bone biopsy was taken with a 1.4 cm diameter trephine. However, the width of the 12th rib at the bone biopsy sampling site previously described was so narrow in growing animals that the technique was too risky for this animal class. Therefore, bone biopsy samples were taken only from lactating cows.

The bone biopsy technique involved a surgical procedure; therefore, veterinary help was employed when the farmer requested. At the end of the procedure, each animal received an intramuscular antibiotic injection.

Bone samples were separately and properly identified in plastic bottles and frozen for further analysis at the University of Florida.

Liver biopsy

Liver samples were taken in vivo using the liver biopsy technique described by Fick et al. (1979). The same ten random lactating cows and ten growing animals in each farm selected for blood sampling were used for liver biopsy sampling. For each season, a total of 80, 80 and 120 liver samples were collected for the Northeast, Central and Southwest regions, respectively.

The aseptic conditions recommended and the important considerations to prevent contamination of liver samples throughout the procedure were carefully followed as was described by Fick et al. (1979).

Liver samples were frozen immediately after collection. Identification of samples was completed by writing the sample number on the container corresponding to the same number of the blood plasma.

Chemical Analysis

Soil and Forage Samples

Soil samples were analyzed according to the procedures used by IFAS extension soil testing laboratory in Gainesville, Florida (Mitchell and Rhue, 1979). The soil samples were analyzed for organic matter, pH, soluble salts, aluminum, calcium, potassium, magnesium, sodium, phosphorus, iron, copper, manganese and zinc. Minerals were extracted from soils using Mehlich I extracting solution method (.05 N HCl + .025 N H_2SO_4). This extractant was formerly referred to as the double-acid extractant by the Soil Science Society of America (Rhue and Kidder, 1983). Soil mineral concentrations were determined by atomic absorption spectrophotometry (Perkin-Elmer, 1973).

Forage samples were processed and analyzed for mineral content according to methods described by Fick et al. (1979). Calcium, potassium, magnesium, sodium, iron, copper, manganese and zinc were analyzed by atomic absorption spectrophotometry (Perkin-Elmer, 1980). Cobalt and molybdenum were analyzed by flameless atomic absorption spectrophotometry using a Perkin-Elmer AAS 503 equipped with a graphite furnace and D_2 corrector. Phosphorus was determined by the colorimetric method described by Harris and Popat (1954) and included by Fick et al. (1979) as a method for phosphorus determination for plant and animal tissue. Selenium in forage samples was analyzed by a modification of the fluorometric method by Whetter and Ullrey (1978).

Finally, crude protein concentrations in forages were determined by measuring total nitrogen, following the method of Technicon Industrial Systems (1978) for that purpose.

Animal Tissue Samples

Blood plasma samples were deproteinized with 10% trichloroacetic acid (TCA) and then analyzed for mineral content according to the method described by Fick et al. (1979). Calcium, magnesium, copper and zinc were analyzed by atomic absorption spectrophotometry (Perkin-Elmer 5000). Phosphorus was determined by the colorimetric technique (Harris and Popat, 1954), and selenium was analyzed using the modified fluorometric method (Whetter and Ullrey, 1978).

Specific gravity was measured for bone samples according to the procedures of Little (1972) as modified by Mtimuni (1982) and other students in the Nutrition Laboratory at the University of Florida. The following describes the procedure used: Air-dried bone biopsy was weighed in air on an analytical balance. A soft piece of stainless steel wire about 15 cm in length with a hook at both ends was weighed in air and later in water kept at 4°C in a 100 ml beaker. The wire was suspended from the balance by a hook and immersed into the water at the same level samples were to be immersed in water. The samples were dried and extracted in ether following procedures outlined by Fick et al. (1979) and subsequently analyzed for calcium, magnesium and phosphorus.

Liver biopsy sample preparation was carried out as described by Fick et al. (1979). Dry tissue samples (approximately .3 g) were pre-ashed on a hot plate with 50% (v/v) nitric acid and then ashed overnight in a muffle furnace at increments of 100°C every hour until reaching 550°C. Ash was solubilized first with 50% nitric acid, then with 10% nitric acid and finally, with distilled water. Solutions were filtered, diluted to appropriate range and analyzed with atomic absorption spectophotometry for copper, iron, manganese and zinc (Perkin-Elmer, 1980). Liver cobalt and molybdenum were determined by flameless atomic absorption spectrophotometry using a Perkin-Elmer AAS 503 equipped with a graphite furnace and D_2 corrector. Selenium analysis was carried out by the modified fluorometric technique previously described (Whetter and Ullrey, 1978).

Statistical Analysis

Soil, forage and animal samples were collected from three regions, as was previously stated. These were the Northeast, Central and Southwest regions. The number of farms sampled in each region was four, four and six, respectively. Samples were taken in both the rainy and dry seasons.

The data from each season were analyzed separately and statistically analyzed using a nested design model with proportional subclass numbers (Snedecor and Cochran, 1973); however, balance sampling was obtained. Data were analyzed by the General Linear Model procedure of the Statistical Analysis System (SAS Institute, Inc., 1982).

Soil, Forage and Bone

For soil, forage and bone data, the basic model used in the analysis was as follows:

$$Y_{ijk} = \mu + R_i + F_{j(i)} + \varepsilon_{k(j(i))}$$

where,

μ = Overall mean

R_i = Fixed effect of ith region

$F_{j(i)}$ = Random effect of jth farm within region i

$\varepsilon_{k(j(i))}$ = Random component of error

From the expected mean squares under this model, differences among regions were tested using the farms/regions mean squares as an error term.

When significant differences among regions were detected, the multiple range test (Duncan, 1955) was used to test differences between regional least square means. However, certain changes in the test procedure were required because of the two random components in the model and the fact that region means were based on different numbers of observations.

Correlation coefficients were estimated in soil and forage.

Blood Plasma and Liver

For blood plasma and liver data, animals were divided into two classes (lactating cows and growing animals). This introduced a third random component into the model as follows:

$$y_{ijkl} = \mu + R_i + F_{j(i)} + C_l + RC_{l(i)} + FC_{l(j(i))} + \varepsilon_{k(j(i))}$$

where,

μ = Overall mena

R_i = Fixed effect of ith region

$F_{j(i)}$ = Random effect of jth farm within region i

C_l = Fixed effect of lth class

$RC_{l(i)}$ = Interaction effect of lth class within region i

$FC_{l(j(i))}$ = Interaction effect of lth class in jth farm within region i

$\varepsilon_{k(j(i))}$ = Random component of error

As a result, both class and region x class were tested using (farms/regions) x class mean square as an error term. Regions were still tested with the farms/regions mean square.

Duncan's test (Duncan, 1955) procedure for comparing regions was not affected by the addition of class as a factor in the experiments. However, certain changes in the test procedure were required due to sample size for regions.

Finally, the correlation coefficients between plasma and liver responses were estimated. These estimates were obtained for each region and class separately for the rainy and dry seasons.

CHAPTER IV

EVALUATION OF THE MINERAL STATUS OF CATTLE IN SPECIFIC REGIONS IN GUATEMALA. I. MACROELEMENTS, CRUDE PROTEIN, AND OTHER SOIL AND BONE PARAMETERS

Introduction

Undernutrition is commonly accepted to be the most important limitation to herbivore livestock production in tropical countries (McDowell et al., 1983). In addition, mineral deficiencies, imbalances and toxicities have been reported to severely inhibit tropical cattle production systems (McDowell, 1976). Scaillet (1969) stated the need for mineral supplementation in Guatemala of sodium and phosphorus since more than 70% of the forages under study were found below the critical concentration of phosphorus ($< .25\%$ dry basis), according to the critical level for beef cattle stated by the NRC (1976). Similarly, in the 1974 Latin American Tables of Feed Composition, the percentages of forage samples deficient in these elements were 60% for sodium and 73% for phosphorus, and the authors concluded that phosphorus deficiency is the most widespread and economically important of all the mineral deficiencies affecting grazing livestock (McDowell et al., 1977a). Therefore, adequate supplemental feeding of minerals which are frequently deficient in tropical forages can improve livestock production and result in a beneficial cost-to-benefit ratio.

The purpose of this study was to evaluate the mineral status of three cattle-producing regions of Guatemala. In the present chapter, the status of macrominerals and protein of cattle in specific regions of Guatemala is determined while Chapter V evaluates trace mineral status.

Materials and Methods

Soil, forage and animal tissue samples were collected from 14 different farms within three regions in Guatemala during the rainy and dry seasons. Collections were made at four, four and six farms within the Northeast, Central and Southwest regions, respectively, for each season. Sampling periods corresponded to the middle of the rainy season (July-August, 1980) and the middle of the dry season (February-March, 1982). A total of 42 soil, 84 forage, 280 blood plasma and 28 bone biopsy samples were obtained for each of the sampling periods.

Each of the three composite soil samples for each farm came from 20 to 25 samples. The soil sampling technique used was described by Bahia (1978). Soil samples were analyzed according to the procedures used by IFAS extension soil testing laboratory in Gainesville, Florida (Mitchell and Rhue, 1979). Soil samples were analyzed for organic matter, pH, soluble salts, aluminum, calcium, potassium, magnesium, sodium and phosphorus. Minerals were extracted from soils using the Mehlich I extracting solution method (.05N HCl + .025N H_2SO_4).

Six composites of the major species of unfertilized forage samples from each farm were collected during each of the sampling periods. Forage samples were processed and analyzed for mineral content according to methods described by Fick et al. (1979).

Blood plasma and bone samples were collected from beef cattle from each farm within each region. The animals were divided into two classes, pregnant-lactating cows (from 3 to 10 years old) and growing animals (steers from 1 to 2 years of age). The majority of animals were Zebu-Criollo with variable degrees of crossbreeding. Blood plasma was collected for each season from 10 lactating cows and 10 growing animals from each farm. Two bone biopsy samples from lactating cows were collected at each farm and were taken as described by Little (1972).

Forage calcium, potassium, magnesium and sodium, blood plasma and bone calcium and magnesium were determined by atomic absorption spectrophotometry (Perkin-Elmer, 1980). Forage, blood plasma and bone phosphorus were determined by the colorimetric method of Harris and Popat (1954). Bone specific gravity was measured using the method of Little (1972). Finally, crude protein concentrations in forages were determined by measuring total nitrogen following the method of Technicon Industrial Systems (1978).

The data from each season were analyzed separately and statistically analyzed using a nested design model with proportional subclass numbers (Snedecor and Cochran, 1973). However, balance sampling was obtained. Data were analyzed by the General Linear Model procedure of the Statistical Analysis System (SAS Institute, Inc., 1982). When significant differences among regions were detected, the multiple range test (Duncan, 1955) was used to test differences between regional least square means. Correlation coefficients between minerals were estimated.

Results and Discussion

Soil Analyses

Results of soil analyses as related to season and region are presented in table 12. Results of analysis of variance are shown in appendix table 25 and the number of deficiencies are presented in appendix table 26.

Soil organic matter tended to be higher in the Central region in comparison to the Northeast and Southwest during the rainy season. The same trend was found for the dry season, in which a higher ($P < .05$) value for

TABLE 12. SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MACROMINERAL ANALYSES AS RELATED TO SEASON AND REGION (DRY BASIS)

			Region										
			Northeast			Central			Southwest			Overall	
Parameter	Critical level	Season	Mean[a]	S.E.[b]	% Def.	Mean	S.E.	% Def.	Mean	S.E.	% Def.	Mean	% Def.
Organic matter, %		Rainy	4.2	0.9		5.1	0.9		3.9	0.7		4.3	
		Dry	4.9^f	1.6		13.2^e	1.6		5.9^{ef}	1.3		7.7	
pH		Rainy	6.2	0.4		5.9	0.4		5.9	0.3		6.0	
		Dry	5.7^f	0.1		5.9^{ef}	0.1		6.3^e	0.1		6.0	
Soluble salts, ppm		Rainy	504	228		767	228		874	186		738	
		Dry	246	56		298	56		221	46		250	
Al, ppm		Rainy	241	48		359	48		314	39		306	
		Dry	222	89		478	89		332	72		342	
Ca, ppm	< 71[c]	Rainy	1972	481	0	1924	481	0	2222	393	0	2065	0
		Dry	1512	207	0	1519	207	0	1840	169	0	1654	0
K, ppm	< 62[d]	Rainy	191	189	17	551	189	0	254	155	6	321	7
		Dry	159^f	75	33	463^e	75	17	294^{ef}	62	0	304	14
Mg, ppm	< 30[d]	Rainy	354	86	0	348	86	0	430	71	0	386	0
		Dry	364	51	0	371	51	0	415	42	0	388	0
Na, ppm		Rainy	46.3	7.4		35.9	7.4		42.7	6.0		41.8	
		Dry	35.3	5.8		19.5	5.8		29.6	4.7		28.3	
P, ppm	< 17[d]	Rainy	17.4	8.6	75	2.1	8.6	100	18.9	7.0	67	13.6	78
		Dry	10.2^g	2.8	75	1.1^h	2.8	100	7.6^{gh}	2.3	83	6.5	93

[a] Least square means based on the following number of samples: 3 samples from each farm, with 4, 4 and 6 farms within Northeast, Central and Southwest regions, respectively, for each of the seasons (rainy and dry).

[b] Standard error of least square mean.

[c] Breland (1976).

[d] Rhue and Kidder (1983).

[e,f] Means among regions in a row with different superscripts differ ($P < 0.05$).

[g,h] Means among regions in a row with different superscripts differ ($P < 0.10$).

organic matter was also found for the Central region and a lower one for the Northeast.

Soil pH was similar for all regions during the rainy season. However, during the dry season, the lower ($P < .05$) pH values were found in the Northeast. Popenoe (1960) indicated that parent material, topography and climate have a very significant effect on the pH of the immature soils in the Polochic Valley in the Northern region of Guatemala.

Aluminum ion is reported to be the dominant cation associated with soil acidity below pH 5.5 (Sanchez, 1976). Since the soil pH was above 5.5 for each of the regions, the values of extractable soil aluminum did not appear to be excessively high. Therefore, under such conditions, aluminum does not have much effect on the reduction of phosphorus and the consequent uptake by plants (Sanchez, 1981).

Among the macroelements, phosphorus presented the highest deficiency (< 17 ppm), with 75, 100 and 67% of samples deficient during the rainy season for the Northeast, Central and Southwest, respectively. Similar percentages of deficiency for each region were found for the dry season. Furthermore, in the dry season, the regions with higher ($P < .10$) soil phosphorus values were the Northeast and Southwest in comparison to the Central region where values were very low (1.1 ppm). Tropical soils are generally reported to be deficient in phosphorus (Volkweiss, 1978). The same results were indicated by Peducassé et al. (1983) in the Bolivian tropics, where phosphorus deficiency was found in 100% of soil samples.

Soil potassium was lower ($P < .05$) in the Northeast region compared to values in the Central and Southwest during the dry season. However, no differences ($P > .05$) among regions were found in the rainy season. Similar information was provided by Popenoe (1960) for the humid tropical climate of the Polochic Valley in Guatemala where clearing and burning of plant material would deposit large amounts of exchangeable potassium in the topsoil.

Among the other soil macroelements, no deficiencies below critical levels were detected for the different regions and seasons. However, extractable soil calcium for both seasons tended to be higher in the Southwest soils in contrast to soils of the Northeast and Central regions. Based on critical levels of < 71 ppm soil calcium for normal plant growth (Breland, 1976), none of the samples were deficient in calcium in each of the three regions. A similar tendency was found for soil magnesium, with no differences among regions in each season and samples not deficient, based on a critical value of < 30 ppm (Rhue and Kidder, 1983).

Soil organic matter, pH, soluble salts and macromineral correlation coefficients as related to season are presented in appendix table 27. Calcium and pH were positively correlated ($P < .01$) for both the rainy (.74) and dry (.68) seasons. However, region has an effect on the parameter pH in the dry season; thus the estimate of the correlation could be misleading. Aluminum ion, the predominant cation associated with soil acidity (Sanchez, 1976), had only a low negative correlation ($< -.5$) with pH. This may be due to the pH of the soils which was above 5.5 when aluminum ions are precipitated out of solution (Mtimuni, 1982). Other degrees in the association between different soil parameters are presented in appendix table 27.

Forage Analyses

Forage macromineral and crude protein concentrations for the rainy and dry seasons in the three regions are shown in table 13, compared to critical concentrations suggested by McDowell et al. (1983). Results of

TABLE 13. FORAGE MACROMINERAL AND CRUDE PROTEIN CONCENTRATIONS AS RELATED TO SEASON AND REGION (DRY BASIS)

			Region										
			Northeast			Central			Southwest			Overall	
Parameter	Critical level[a]	Season	Mean[b]	S.E.[c]	% Def.	Mean	S.E.	% Def.	Mean	S.E.	% Def.	Mean	% Def.
Ca, %	< 0.3	Rainy	0.40	0.02	13	0.40	0.03	29	0.26	0.05	47	0.34	32
		Dry	0.37	0.03	58	0.25	0.04	88	0.26	0.05	69	0.29	71
K, %	< 0.8	Rainy	2.82^{d}	0.3	0	2.29^{de}	0.3	8	1.67^{e}	0.24	11	2.18	7
		Dry	2.14^{d}	0.2	8	1.22^{e}	0.2	25	1.14^{e}	0.16	8	1.4	13
Mg, %	< 0.2	Rainy	0.32^{d}	0.03	17	0.22^{de}	0.03	63	0.12^{e}	0.02	94	0.2	63
		Dry	0.26^{d}	0.02	29	0.17^{e}	0.02	96	0.11^{e}	0.01	94	0.17	76
Na, %	< 0.06	Rainy	0.08	0.02	54	0.07	0.02	58	0.11	0.02	53	0.09	55
		Dry	0.04	0.01	79	0.02	0.01	100	0.04	0.01	86	0.03	88
P, %	< 0.25	Rainy	0.29	0.04	63	0.25	0.04	63	0.25	0.04	61	0.26	60
		Dry	0.29^{d}	0.03	33	0.26^{de}	0.03	50	0.17^{e}	0.03	78	0.23	57
CP, %	< 7	Rainy	8.4	1	42	10.5	1	17	7.8	0.8	47	8.8	37
		Dry	7.9	1	33	6.6	1	50	5.3	0.8	78	6.4	57

[a] McDowell et al. (1983).

[b] Least square means based on the following number of samples: 6 samples from each farm, with 4, 4 and 6 farms within Northeast, Central and Southwest regions, respectively, for each of the seasons (rainy and dry).

[c] Standard error of least square mean.

[d,e] Means among regions in a row with different superscripts differ ($P < 0.05$).

analysis of variance are presented in appendix table 28, and numbers of deficient forage samples are shown in appendix table 29.

The percentage of total samples found below critical concentrations for the Northeast, Central and Southwest regions, respectively, during the rainy season were as follows: calcium, 13, 29, 47; potassium, 0, 8, 11; magnesium, 17, 63, 94; sodium, 54, 58, 53; phosphorus, 63, 63, 61; crude protein, 42, 17, 47. Similarly, for the dry season, percentages were: calcium, 58, 88, 69; potassium, 8, 25, 8; magnesium, 29, 96, 94; sodium, 79, 100, 86; phosphorus, 33, 50, 78; crude protein, 33, 50, 78. These data are in agreement with Scaillet (1969) who studied various grass species and legumes in several regions of Guatemala and reported differences among regions with respect to calcium, potassium, magnesium and phosphorus. However, it is important to mention the high deficiency of magnesium which exists in the Central and Southwest regions.

Calcium in forage samples was lower ($P < .05$) in the Southwest region in comparison to the Northeast and Central regions during the rainy season. During the dry season, a similar trend occurred, with the exception of the Central region which had a decline to a value of .25% in forage calcium on a dry basis. During the dry season, 71% of the total samples analyzed from the three regions were deficient in calcium, containing less than a critical level of .30% (McDowell et al., 1983). Mtimuni (1982) in Malawi reported a similar value of 79%, and Vargas (1982) in the Eastern Plains of Colombia reported a value of 95% of forage samples below the critical concentration (< .30%).

During the rainy season, forage potassium content was lower ($P < .05$) in the Southwest region than in the Northeast region, although no difference ($P > .05$) between Northeast and Central regions was found. Since potassium in plants is associated with young growing tissue, it is not surprising that potassium is not a problem when plants are still in the active stage of growth (Gomide, 1978). The same trend was encountered for the dry season, in which a lower ($P < .05$) value for forage potassium was also found for the Southwest region. On the other hand, the multiple range test (Duncan, 1955) that was utilized to test significant differences between regional least square means did not find differences ($P > .05$) between the Central and Southwest regions. Individual evaluation of samples based on the critical potassium level of .8% as suggested by McDowell et al. (1983) indicated that the region with the highest percentage of samples below the critical concentration during the dry season was the Central region. According to Scaillet (1969), the average potassium content in the different grasses of Guatemala is in the range between 1.5 and 2.5%, although in some parts of the Northern region of the country, the grasses have potassium values of 1%. The results in table 13, and the information provided by Scaillet (1969) indicates that forage potassium concentration in the majority of cases is higher than the requirements for beef cattle suggested by McDowell et al. (1983).

Magnesium in forages from the Southwest region was lower ($P < .05$) than in those from the Northeast; however, no difference ($P > .05$) between Southwest and Central regions was found during the rainy season. A similar trend in forage magnesium concentration for each region was encountered during the dry season (table 13). Furthermore, the percentage of total samples found below critical concentrations for each of the regions was higher, with the exception of the Southwest region which remained the same (94%).

Reid and Horvath (1980) indicated the effect of acid, sandy, highly leached soils and potassium fertilization on the impaired absorption and reduced availability of magnesium to the plant. Therefore, an explanation for the high percentages of total samples detected below critical concentrations in forage magnesium could be due to soils with relatively high amounts of potassium as was found in the Central and Southwest reions and soil pH values below the optimum 7 to 8.5 for adequate magnesium absorption by plants. In addition, the practice of clearing and burning of plant material in Guatemala which would deposit large amounts of exchangeable potassium in the topsoil was reported by Popenoe (1960).

The results for forage magnesium (table 13) are in contradiction with the data of Scaillet (1969), who concluded that forage magnesium was in the range of .15 to .30% (dry basis) and was not a problem since the critical level was considered to be less than .1%. On the other hand, low forage magnesium concentrations are in agreement with studies by Vargas (1982) in Colombia and Mtimuni (1982) in Malawi.

Sodium concentrations in forages among the three regions were not different (P > .05) during either season. However, greater values were found for the rainy season in comparison to the dry season. Individual evaluation of samples based on dietary sodium requirement of .06% for mature cows (McDowell et al., 1983) indicated that none of the forage samples in the Central region had adequate sodium during the dry season. An analogous situation occurs for the Northeast and Southwest regions in which 79 and 86%, respectively, of the forage sodium samples were found below the criticial concentration of less than .06%. A similar conclusion was reported by Scaillet (1969), who indicated that forage sodium in different regions of Guatemala was insufficient and needs to be supplemented to grazing cattle.

Forage phosphorus concentrations were similar for the three regions during the rainy season (table 13). In contrast, differences ($P < .05$) among regions were found during the dry season. The Central and Southwest regions did not differ ($P > .05$), yet the Northeast was higher ($P < .05$) than the Southwest. Individual evaluation of samples based on critical concentration on a farm basis for forage phosphorus, according to McDowell et al. (1983), appears in appendix table 29. Of all samples analyzed, 60% were deficient in phosphorus (<.25%) during the rainy season and 57% were deficient during the dry season. Scaillet (1969) pointed out that a level of .3% phosphorus was considered as the minimum concentration required for an economic cattle operation in Guatemala. Furthermore, the author indicated that phosphorus concentration ranges in the regions of Coban (Northern) and Jalapa (Southeast) were very low, with values between .1 and .12% (dry basis). In the Southwest region, there was a marked difference between forage phosphorus concentration in the rainy season versus the dry season. This difference could be due to a depressive influence of flowering and advanced maturity of the plant. Similar results were reported by Scaillet (1969) in the same region when Brachiaria ruziziensis contained .15% phosphorus (dry basis) during the rainy season; after six months of the dry season, phosphorus concentration was below .03%.

Crude protein concentrations were not different ($P > .05$) among regions (table 13) for either season. However, the forage concentration was greater for the three regions during the rainy season in comparison to the dry season. Furthermore, of all samples analyzed, 37% were deficient in crude protein (< 7%) during the rainy season and 57% were deficient in the dry season. Moore (1980) suggested that supplements may improve utilization of available forage by correcting nutrient deficiencies and/or providing additional digestible energy. Therefore, supplemental protein during the dry season in Guatemala may increase voluntary forage intake, energy digestibility and animal performance. The effect of supplemental protein on intake is influenced by forage quality. Mature forages having less than 7 to 8% crude protein are likely to show increased intake due to protein supplementation (Moore, 1980).

Forage macromineral and crude protein correlation coefficients as related to season are presented in appendix table 30. Correlation coefficients ($P < .05$, $r \geq |.5|$) between forages for the rainy season were found as follows: calcium-magnesium ($r = .59$); calcium-crude protein ($r = .52$), potassium-zinc ($r = .58$); magnesium-zinc ($r = .55$); phosphorus-crude protein ($r = .65$). During the dry season, the correlation coefficients ($P < .05$, $r = \pm .5$) were the following: calcium-magnesium ($r = .72$); potassium-mangesium ($r = .57$); potassium-phosphorus ($r = .73$); potassium-molybdenum ($r = .66$); potassium-selenium ($r = .58$); potassium-crude protein ($r = .61$); magnesium-crude protein ($r = .54$); sodium-manganese ($r = .51$); phosphorus-selenium ($r = .58$); phosphorus-crude protein ($r = .80$); crude protein-selenium ($r = .56$). Nevertheless, if the factor (region) has an effect on any of the mineral parameters, then the estimate of the correlation previously stated could be erroneous.

Animal Tissue Analyses

Blood plasma and bone macromineral concentrations as related to season, region and animal class are presented in tables 14 and 15. Results of analysis of variance are shown in appendix table 31 and number of deficient macromineral samples, in appendix tables 32 and 33.

TABLE 14. BLOOD PLASMA AND BONE MACROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION

			Region										
			Northeast			Central			Southwest			Overall	
Parameter	Critical level[a]	Season	Mean[b]	S.E.[c]	% Def.	Mean	S.E.	% Def.	Mean	S.E.	% Def.	Mean	% Def.
Blood Plasma													
Ca, mg/100 ml	< 8	Rainy	8.43	0.07	14	8.50	0.07	15	8.46	0.06	18	8.46	16
		Dry	8.37	0.10	25	8.61	0.10	9	8.46	0.08	17	8.48	17
Mg, mg/100 ml	< 2	Rainy	2.63[e]	0.05	0	2.26[f]	0.05	13	2.25[f]	0.04	13	2.36	9
		Dry	2.49	0.09	3	2.56	0.09	0	2.48	0.07	4	2.51	3
P, mg/100 ml	< 4.5	Rainy	4.67	0.56	43	5.63	0.56	18	5.29	0.46	36	5.21	33
		Dry	5.10	0.51	29	4.79	0.51	43	5.09	0.42	33	4.99	34
Bone (D.M., fat free)													
Ca, %	< 24.5	Rainy	22.50	0.60	100	22.75	0.60	100	22.68	0.49	92	22.65	96
		Dry	22.56	0.72	88	23.44	0.72	63	23.78	0.59	42	23.3	61
Mg, %		Rainy	0.45	0.02		0.50	0.02		0.50	0.02		0.49	
		Dry	0.42	0.02		0.40	0.02		0.39	0.02		0.40	
P, %	< 11.5	Rainy	10.07	0.25	100	10.36	0.25	100	10.05	0.20	92	10.15	96
		Dry	10.10	0.52	100	10.13	0.52	100	10.35	0.42	83	10.21	93
Ash, %	< 66.8	Rainy	63.2	0.6	100	62.3	0.6	100	61.6	0.5	100	62.3	100
		Dry	62.7	1.3	88	65.0	1.3	75	65.2	1.1	75	64.4	79
Spec. grav.[d], g/cm^3	< 1.68	Rainy	1.80[g]	0.04	0	1.69[gh]	0.04	50	1.68[h]	0.03	50	1.72	36
		Dry	1.85	0.06	0	1.96	0.06	0	1.83	0.05	17	1.88	7

[a] McDowell et al. (1983).

[b] Least square means based on the following number of samples: Blood plasma - 20 samples from each farm (10 lactating cows and 10 growing animals) and Bone - 2 samples from each farm (lactating cows), with 4, 4 and 6 farms within Northeast, Central and Southwest regions, respectively, for each season (rainy and dry).

[c] Standard error of least square mean.

[d] Specific gravity.

[e,f] Means among regions in a row with different superscripts differ ($P < 0.05$).

[g,h] Means among regions in a row with different superscripts differ ($P < 0.10$).

TABLE 15. BLOOD PLASMA AND BONE MACROMINERAL CONCENTRATIONS AS RELATED TO SEASON, REGION AND ANIMAL CLASS

			Region						Animal Class					
			Northeast		Central		Southwest		Lactating			Growing		
Parameter	Critical level[a]	Season	Mean[b] Lactating	Mean[c] Growing	Mean Lactating	Mean Growing	Mean Lactating	Mean Growing	Mean[d]	S.E.[f]	% Def.	Mean[e]	S.E.[g]	% Def.
Blood Plasma														
Ca, mg/100 ml	< 8	Rainy	8.35	8.52	8.52	8.49	8.49	8.43	8.45	0.04	19	8.48	0.04	12
		Dry	8.48	8.26	8.59	8.62	8.59	8.33	8.56^h	0.06	11	8.41^i	0.06	22
Mg, mg/100 ml	< 2	Rainy	2.68	2.58	2.28	2.24	2.27	2.22	2.41	0.04	6	2.35	0.04	12
		Dry	2.48	2.50	2.58	2.55	2.47	2.49	2.51	0.03	4	2.51	0.03	1
P, mg/100 ml	< 4.5	Rainy	4.17	5.18	5.50	5.75	4.44	6.13	4.70^j	0.18	45	5.69^k	0.18	20
		Dry	5.06	5.15	4.78	4.72	4.66	5.50	4.83^i	0.16	36	5.12^h	0.16	32
Bone (D.M., fat-free)														
Ca, %	< 24.5	Rainy	22.50		22.75		22.68		22.64	1.7	96			
		Dry	22.56		23.44		23.78		23.26	2.0	61			
Mg, %		Rainy	0.45		0.50		0.50		0.48	0.07				
		Dry	0.42		0.40		0.39		0.40	0.07				
P, %	< 11.5	Rainy	10.08		10.36		10.05		10.16	0.70	96			
		Dry	10.10		10.13		10.35		10.19	1.5	93			
Ash, %	< 66.8	Rainy	63.19		62.31		61.58		62.36	1.8	100			
		Dry	62.68		64.95		65.22		64.28	3.8	79			
Specific gravity, g/cm^3	< 1.68	Rainy	1.80		1.69		1.68		1.72	0.12	36			
		Dry	1.85		1.96		1.83		1.88	0.17	7			

[a] McDowell et al. (1983).

[b,c] Least square means based on the following number of samples: Blood plasma - 10 samples from lactating cows and 10 from growing animals from each farm, and Bone - 2 samples from lactating cows from each farm, with 4, 4 and 6 farms within Northeast, Central and Southwest regions, respectively, for each season (rainy and dry).

[d,e] Least square means based on the following number of samples: Blood plasma - 140 samples from lactating cows and 140 from growing animals, and Bone - 28 samples from lactating cows, for each season (rainy and dry).

[f,g] Standard error of least square mean.

[h,i] Means between animal class within a row with different superscripts differ ($P < 0.10$).

[j,k] Means between animal class within a row with different superscripts ($P < 0.05$).

Blood plasma

Regional and animal class differences were not significant ($P > .05$) in plasma calcium, and all regional least square means values were greater than the critical level of 8 mg/100 ml (McDowell et al., 1983) during the rainy season. The same tendency was observed for the dry season, with no differences ($P > .05$) in blood plasma calcium among regions. However, a difference ($P < .05$) was found between lactating cows and growing animals. A greater mean plasma calcium was encountered for the lactating cow (8.56 mg/100 ml) in comparison to the growing animal (8.41 mg/100 ml). This phenomenon can be explained since milk contains large amounts of calcium and can be withdrawn from bones during periods of increased needs, such as during early lactation when milk production is at its peak (Bath et al., 1978). The incidence of calcium deficiency as percentage of samples below critical levels for the Northeast, Central and Southwest regions, respectively, during the rainy season was 14, 15 and 18, and the overall incidence was 16%. Similarly, for the dry season, the percentages were 25, 9 and 17% for the Northeast, Central and Southwest regions, respectively, and the overall mean incidence of deficiency was 17%. On the other hand, if 9 mg/100 ml blood plasma calcium is considered the critical level (Underwood, 1981), the overall percentage of samples below critical concentration increases substantially. The values for the rainy and dry seasons would increase to 82 and 81%, respectively.

Plasma magnesium was higher ($P < .05$) for the Northeast than for the other two regions. No differences ($P > .05$) in plasma magnesium were found among animal classes; however, a greater value was encountered in lactating cows. Incidence of magnesium deficiency was higher in the Central and Southwest regions, with 13% of samples for both regions below the critical concentration of 2.0 mg/100 ml suggested by McDowell et al. (1983). It is important to mention that these two regions were also deficient in forage magnesium during the rainy season. No differences ($P > .05$) among regions or animal class were found during the dry season, although the overall incidence of plasma magnesium decreased to 3%. McDowell et al. (1983), in a review of the diagnosis of specific mineral deficiencies and toxicities in cattle, reported that plasma magnesium levels of 1 to 2 mg/100 ml are considered deficient, and a level of less than 1 mg/100 ml indicates danger of tetany.

Plasma phosphorus is not recommended as a practical criterion for assessing phosphorus status of grazing animals (CMN, 1973). However, if the methods of collection and sample preparation are controlled, it is considered a good measurement. Therefore, blood phosphorus values continue to be reported in the literature. Plasma phosphorus was not different ($P > .05$) among regions during the rainy season; however, a difference ($P < .05$) between lactating cows and growing animals was found, with 4.7 and 5.7 mg/100 ml, respectively. The Northeast region showed the maximum value (43%) of samples below the critical concentration of 4.5 mg/100 ml suggested by McDowell et al. (1983), followed by the Southwest region (36%) and the Central region (18%). The overall percentage incidence of deficiency was 33%. Plasma phosphorus was greater in the Northeast and Southwest regions during the dry season in comparison to the Central region, although no differences ($P > .05$) among regions were found. However, growing animals had higher ($P < .05$) levels than lactating cows (5.1 and 4.8 mg/100 ml, respectively). The overall percentage of deficeint samples below the critical concentration (< 4.5 mg/100 ml) according to McDowell et al. (1983) was 34. There are many factors which could affect the amount of phosphorus in plasma. The phosphorus level in blood is not nearly as constant as the calcium level; this is not difficult to understand since blood phosphorus is in equilibrium, not only with bone phosphorus, but with that arising from a large number of organic phosphorus compounds produced as a result of cellular metabolism (Irving, 1973).

Bone

Bone biopsy samples were taken only from pregnant-lactating cows. Mean rib bone macromineral concentrations as related to season and region and suggested critical levels are presented in table 14.

There was no variation ($P > .05$) among regions in any of the bone parameters analyzed for each of the seasons, with the exception of specific gravity during the rainy season in which a difference ($P < .10$) between the Northeast and Southwest regions was found. Nevertheless, the percentage of deficiencies below the critical concentrations suggested by McDowell et al. (1983) for each parameter in each season and region was high.

Bone calcium did not show significant differences ($P > .05$) among regions in either the rainy or the dry season. Means of lactating cow bone calcium (dry matter, fat-free) were below the critical level of 24.5% for normal animals (Little, 1972). Furthermore, individual evaluation of samples indicated that 96 and 61% of all samples analyzed were deficient in calcium for the rainy and dry seasons, respectively. Similar results were reported by Vargas (1982) in the Eastern Plains of Colombia, who indicated that 61% of samples were below the critical level during the rainy season and 81% during the dry season. Working in the tropics of Bolivia, Peducassé (1982) found 100% of bone samples below critical levels for calcium. The significant incidence of calcium deficiency indicated by bone calcium is not in agreement with the low incidence of calcium deficiency in blood plasma. This phenomenon, in part, can be explained by the fact that blood calcium is controlled by the parathyroid hormone, calcitonin (Guyton, 1966), and 1-25 $(OH)_2$ cholecalciferol; therefore, only in extreme deficiency could blood calcium be low (CMN, 1973; Boris et al., 1978).

Bone magnesium was similar among regions in both the rainy and dry seasons. Nevertheless, higher values were found in the rainy season for each region in contrast to the dry season.

Bone phosphorus did not show variation ($P > .05$) among regions in the rainy season or in the dry season. Least square means for bone phosphorus in all regions were below the critical level of 11.5% for normal cattle (Little, 1972). Overall percentages of deficient samples for the rainy and dry seasons, respectively, were 96 and 93%. Vargas (1982) reported that 90% of total samples were below the critical concentration of bone phosphorus in the rainy season and 100% in the dry season. Cohen (1973) suggested that bone provides a more reliable method for assessing calcium and phosphorus than blood.

Bone ash did not show variation ($P > .05$) among the regions for either season. However, the percentage of samples below the critical concentration suggested by McDowell et al. (1983) for bone ash ($< 66.8\%$ dry matter, fat-free) was 100% for all regions for the rainy season. Similar results were obtained for the dry season, in which an overall 79% of samples were below critical concentrations.

The specific gravity value for the Northeast region was greater ($P < .10$) than for the Central and Southwest regions during the rainy season. No variation ($P > .05$) in specific gravity among regions was found for the dry season. Nevertheless, due to lack of agreement among bone parameters in ranking the three regions in incidence of calcium and phosphorus deficiencies, specific gravity would seem to be a reliable criterion for assessing mineral status of bone.

Relationship of minerals

Blood plasma and bone macromineral correlation coefficients as related to season are presented in appendix table 34. Considering values of correlation coefficients greater than or equal to $|.5|$ at a significance level of $P < .05$, only bone calcium and bone phosphorus correlated positively at a .01 probability level in both seasons. Similarly, bone ash and bone specific gravity correlated positively at a .01 probability level during the dry season. However, if the factor (region) has an effect on any of the stated minerals, then the estimated correlation could be misleading.

Results of correlation coefficients between blood plasma macroelements and liver microelements (Chapter V) as related to season, region and animal class are shown in appendix table 35. It is of importance to mention the negative correlation that exists between blood plasma phosphorus and liver copper, regardless of animal class. A similar relationship was reported by Mtimuni (1982); however, no statistical variation ($P > .05$) was found. The author concluded that mineral concentrations between animal tissues did not correlate with each other with a correlation coefficient greater or equal to $|.5|$ at the probability level of .05. This clearly demonstrated the problem of finding significant correlation coefficients between soil, forage and animal tissues (Conrad et al., 1980).

Summary and Conclusions

A study was conducted to determine the macromineral status of three cattle-producing regions in Guatemala and to compare animal classes (pregnant-lactating cows and growing steers). Soil, forage, blood and rib bone samples were collected at four, four and six farms within the Northeast, Central and Southwest regions, respectively, for each season. Sampling periods corresponded to the middle of the rainy season (July-August, 1980) and the middle of the dry season (February-March, 1982). Percentages of nutrient concentrations below critical levels (in parentheses) and suggestive of deficiency for the Northeast, Central and Southwest regions, respectively, for the rainy season were as follows: Soil (ppm) - calcium (71) 0, 0, 0; potassium (62) 17, 0, 6; magnesium (30) 0, 0,0; phosphorus (17) 75, 100, 67; Forage - calcium (.30%) 13, 29, 47; potassium (.80%) 0, 8, 11; magnesium (.20%) 17, 63, 94; sodium (.06%) 54, 58, 53; phosphorus (.25%) 63, 63, 61; protein (7%) 42, 17, 47; Blood plasma (mg/100 ml) - calcium (8) 14, 15, 18; magnesium (2) 0, 13, 13; phosphorus (4.5) 43, 18, 36; Bone (dry matter, fat-free %) - calcium (24.5) 100, 100, 92; phosphorus (11.5) 100, 100, 92; bone ash (66.8) 100, 100, 100. In the dry season, the percentages were as follows: Soil (ppm) - calcium (71) 0, 0, 0; potassium (62) 33, 17, 0; magnesium (30) 0, 0, 0; phosphorus (17) 75, 100, 83; Forage - calcium (.30%) 58, 88, 69; potassium (.80%) 8, 25, 8; magnesium (.20%) 29, 96, 94; sodium (.06%) 79, 100, 86; phosphorus (.25%) 33 , 50, 78; protein (7%) 33, 50, 78; Blood plasma (mg/100 ml) - calcium (8) 25, 9, 17; magnesium (2) 3, 0, 4; phosphorus (4.5) 29, 43, 33; Bone (dry matter, fat free %) - calcium (24.5) 88, 63, 42; phosphorus (11.5) 100, 100, 83; bone ash (66.8) 88, 75, 75. Differences ($P < .05$) between lactating cows and growing animals were found in plasma calcium and phosphorus in the dry season and plasma phosphorus ($P < .10$) in the rainy season. On the basis of the analyses, nutrients most likely deficient for each region in both seasons were calcium, sodium, phosphorus and protein in the Northeast, and calcium, magnesium, sodium, phosphorus and protein in the Central and Southwest.

CHAPTER V
EVALUATION OF THE MINERAL STATUS OF CATTLE IN SPECIFIC REGIONS IN GUATEMALA. II. MICROELEMENTS

Introduction

Grazing livestock in tropical countries do not receive mineral supplementation except for common salt and must depend almost exclusively upon forages for their requirements (McDowell et al., 1983). The Latin American Tables of Feed Composition (McDowell et al., 1974) indicated that the percentage of forage samples deficient in the different microelements were as follows: iron, 24%; cobalt, 43%; copper, 47%; manganese, 21%; zinc, 75%. Scaillet (1969) stated that mineral supplementation of the microelement copper in ruminants is needed in the mountain regions in Guatemala, especially in those areas dedicated to sheep production. In addition, the author reported ranges of variation in forage micromineral concentrations on a dry matter basis as follows: iron, 200 to 750 ppm; copper, 8 to 50 ppm; manganese, 10 to 170 ppm.

In order to have rapid and economical improvement in beef cattle production in Guatemala, as in other tropical countries, factors influencing the mineral status of ruminants under grazing conditions must be determined. The purpose of this research was to investigate and evaluate the micromineral status of three cattle-producing regions of Guatemala.

Materials and Methods

Soil, forage and animal tissue samples were collected from different farms within three regions in Guatemala during the rainy and dry seasons. Collections were made at four, four and six farms within the Northeast, Central and Southwest regions, respectively, for each season. Sampling periods corresponded to the middle of the rainy season (July-August, 1980) and the middle of the dry season (Feburary-March, 1982). A total of 42 soil, 84 forage, 280 blood plasma and 280 liver biopsy samples were obtained for each of the sampling periods.

Each of the three composite soil samples for each farm came from 20 to 25 samples. The soil sampling technique was described by Bahia (1978). Soil samples were analyzed according to the procedures used by the IFAS extension soil testing laboratory in Gainesville, Florida (Mitchell and Rhue, 1979). Soil samples were analyzed for iron, copper, manganese and zinc. Minerals were extracted from soils using the Mehlich I extraction solution method (.05 N HCl + .025 N H_2SO_4), and concentrations were determined by atomic absorption spectrophotometry (Perkin-Elmer, 1973).

Six composite samples of the major species of unfertilized forage from each farm were collected during each of the sampling periods. Forage samples were processed and analyzed for mineral content according to methods described by Fick et al. (1979).

Blood plasma and liver samples were collected from beef cattle from each farm within each region. The animals were divided into two classes, pregnant-lactating cows (from 3 to 10 years old) and growing animals (steers from 1 to 2 years of age). The majority of the animals were Zebu-Criollo with varying degrees of crossbreeding. Blood plasma and liver biopsy samples were collected from 10 lactating cows and 10 growing animals from each farm using the technique described by Fick et al. (1979).

Selenium analyses of forages, blood and liver were carried out using the fluorometric technique described by Whetter and Ullrey (1978). Forage iron, copper, manganese and zinc, blood plasma copper and zinc, and liver iron, copper, manganese and zinc were determined using atomic absorption (Perkin-Elmer, 1980). An atomic absorption spectrophotometer equipped with a graphite furnace and D_2 corrector (Perkin-Elmer Model 503) was used to determine forage and liver cobalt and molybdenum.

The data from each season were analyzed separately and statistically analyzed using a nested design model with proportional subclass numbers (Snedecor and Cochran, 1973). However, balance sampling was obtained. Data were analyzed by the General Linear Model procedure of the Statistical Analysis System (SAS Institute, Inc., 1982). When significant differences among regions were detected, the multiple range test (Duncan, 1955) was utilized to test differences between regional least square means. Correlation coefficients between minerals were estimated.

Results and Discussion

Soil Analyses

Results of soil micromineral analysis as related to season and region are presented in table 16. Results of analysis of variance are shown in appendix table 36, and number of deficiencies are presented in appendix table 37.

Soil iron was higher ($P < .05$) in the Northeast region in comparison to the Central and Southwest during the rainy season. A similar trend was found for the dry season; however, the value of soil iron in the Northeast was substantially higher in contrast to the rainy season (160 vs 91 ppm, respectively). The percentages of samples below the critical concentration suggested by Viets and Lindsay (1973) for soil iron (< 2.5 ppm) were as follows: 0, 8 and 6 in the rainy season and 0, 33 and 11 in the dry season for the Northeast, Central and Southwest regions, respectively. Of all samples analyzed in the dry season, 14% were deficient in iron.

TABLE 16. SOIL MICROMINERAL ANALYSES AS RELATED TO SEASON AND REGION (DRY BASIS)

			Region										
			Northeast			Central			Southwest			Overall	
Parameter	Critical level	Season	Mean[a]	S.E.[b]	% Def.	Mean	S.E.	% Def.	Mean	S.E.	% Def.	Mean	% Def.
Fe, ppm	< 2.5[c]	Rainy	90.6^{e}	13.0	0	29.4^{f}	13.0	8	14.9^{f}	10.6	6	40.7	5
		Dry	159.9^{e}	22.5	0	26.1^{f}	22.5	33	21.4^{f}	18.3	11	62.3	14
Cu, ppm	< 0.3[d]	Rainy	2.6	2.3	8	1.5	2.3	33	4.2	1.9	0	3.0	12
		Dry	3.3^{e}	0.4	0	1.1^{f}	0.4	33	1.3^{f}	0.4	17	1.8	17
Mn, ppm	< 5[d]	Rainy	49.4^{gh}	40.5	0	154.4^{g}	40.5	25	12.7^{h}	33.0	6	63.7	10
		Dry	47.2	27.4	0	98.0	27.4	17	29.5	22.4	0	54.1	5
Zn, ppm	< 1[d]	Rainy	5.9	2.1	0	5.0	2.1	8	5.8	1.8	0	5.6	2
		Dry	4.7	1.4	0	5.7	1.4	17	6.8	1.2	0	5.9	5

[a] Least square means based on the following number of samples: 3 samples from each farm, with 4, 4 and 6 farms within Northeast, Central and Southwest regions, respectively, for each of the seasons (rainy and dry).

[b] Standard error of least square mean.

[c] Viets and Lindsay (1973).

[d] Rhue and Kidder (1983).

[e,f] Means among regions in a row with different superscripts differ ($P < 0.05$).

[g,h] Means among regions in a row with different superscripts differ ($P < 0.10$).

Lindsay (1972) indicated that the solubility of iron in soils is largely controlled by the solubility of hydrous iron (III) oxides and that the total inorganic iron in solution varies with pH. Therefore, these relatively high amounts of iron in the Northeast region and low pH values close to 5.7 during the dry season could reduce the availability of phosphorus to plants.

Regional differences were not significant ($P > .05$) in extractable soil copper during the rainy season. However, differences ($P < .05$) among regions were found during the dry season. The Central and Southwest regions had lower ($P < .05$) values, less than one-half as much as the Northeast region. The percentage of samples below the critical level recommended by Rhue and Kidder (1983) was relatively high in the Central region (33%). The overall samples deficient in extractable soil copper for the rainy and dry seasons, respectively, were 12 and 17%. These data of soil copper during the dry season are in agreement with the results of Sanders (1982) which indicated that as the pH increases, the quantity of copper adhered to soil components increased and the proportion of copper in soil solution as cupric ion decreased.

Extractable soil manganese varied ($P < .10$) among regions during the rainy season, with no variation ($P > .10$) found in the dry season. Least square mean soil manganese was relatively high in the Central region for both seasons. Nevertheless, the percentage of samples below the critical level in the Central region was also high (25 and 17% for the rainy and dry seasons, respectively) in comparison to the other two regions. It is important to mention that the Central region is characterized by soils of volcanic origin. Therefore, the high soil manganese concentration can be explained. Lang (1971), in a region of Costa Rica also characterized by volcanic soils, reported similar observations.

Variation in extractable soil zinc was not significant ($P > .05$) among regions for either season. Individual evaluation of samples based on a critical level of less than 1 ppm for normal plant growth (Rhue and Kidder, 1983) when pH is below 6.5 indicated 2% of all samples analyzed were deficient in zinc during the rainy season and 5% during the dry season. These results are not in agreement with values reported by Popenoe (1960) in his study of the Polochic Valley in Guatemala which indicated that the zinc content of soils was probably in the deficient range (< 1 ppm), although differences in soil zinc at different depths in the soil profile were found.

Soil micromineral correlation coefficients as related to season are presented in appendix table 38. Considering correlation coefficients ($P < .05$, $r \geq |.5|$) between soils during the rainy season, only a relationship between copper and phosphorus ($r = .61$) was found. During the dry season, the correlation coefficients ($P < .05$, $r \geq |.5|$) between soil values were as follows: iron-pH ($r = -.59$); iron-copper ($r = .71$); manganese-soluble salts ($r = .60$); manganese-potassium ($r = .55$); zinc-soluble salts ($r = .52$). Nevertheless, if the factor (region) has an effect on any of the soil parameters, then the estimate of the correlations previously stated could be erroneous.

Forage Analyses

The results of forage micromineral analyses as related to season and region are presented in table 17. Results of analysis of variance are shown in appendix table 39, and the number of deficient microminerals in forage samples are presented in appendix table 40.

Forage iron was different ($P < .05$) among regions for either season. Individual evaluation of samples based on iron requirements of 30 ppm

TABLE 17. FORAGE MICROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION (DRY BASIS)

			Region										
			Northeast			Central			Southwest			Overall	
Parameter	Critical level[a]	Season	Mean[b]	S.E.[c]	% Def.	Mean	S.E.	% Def.	Mean	S.E.	% Def.	Mean	% Def.
Fe, ppm	< 30	Rainy	353	127	0	513	127	0	304	104	0	378	0
		Dry	815	185	0	498	185	0	667	151	0	661	0
Co, ppm	< 0.1	Rainy	0.35	0.07	8	0.36	0.07	0	0.36	0.05	3	0.36	4
		Dry	0.48	0.08	4	0.35	0.08	0	0.33	0.07	0	0.38	1
Cu, ppm	< 10	Rainy	9	16	63	32	16	50	21	13	61	21	58
		Dry	5	9	100	20	9	75	3	7	97	8	92
Mn, ppm	< 40	Rainy	155	32	8	70	32	38	64	27	44	92	32
		Dry	154	35	13	69	35	29	69	29	28	93	24
Mo, ppm	> 6	Rainy	1.75^{d}	0.31	0	0.77^{de}	0.31	0	0.5^{e}	0.26	0	0.94	0
		Dry	1.25^{d}	0.2	0	0.27^{e}	0.2	0	0.37^{e}	0.17	0	0.59	0
Se, ppm	< 0.1	Rainy	0.33^{d}	0.03	0	0.08^{e}	0.03	88	0.05^{e}	0.03	89	0.14	63
		Dry	0.75^{d}	0.18	4	0.51^{de}	0.18	50	0.1^{e}	0.15	78	0.4	49
Zn, ppm	< 30	Rainy	38^{f}	4	33	34^{fg}	4	54	26^{g}	3	83	32	61
		Dry	35	6	33	43	6	38	26	5	67	33	49

[a] McDowell et al. (1983).

[b] Least square means based on the following number of samples: 6 samples from each farm, with 4, 4 and 6 farms within Northeast, Central and Southwest regions, respectively, for each of the seasons (rainy and dry).

[c] Standard error of least square mean.

[d,e] Means among regions in a row with different superscripts differ ($P < 0.05$).

[f,g] Means among regions in a row with different superscripts differ ($P < 0.10$).

(McDowell et al., 1983) indicated that none of the forage samples were deficient in iron. The zero incidence of iron deficiency in forages during both the rainy and dry seasons is in agreement with generally adequate concentrations of soil iron. Similar results were reported by Vargas (1982) in the Eastern Plains of Colombia, who indicated that no forage samples were deficient in iron. Scaillet (1969), studying various grass species in several regions of Guatemala, found that the iron concentration of forages varied between 200 and 750 ppm (dry basis).

With the exception of phosphorus and copper, cobalt deficiency is the most severe mineral limitation to grazing livestock in tropical countries (McDowell et al., 1983). Forage cobalt was not different ($P > .05$) among regions in either the rainy or the dry season. However, there was a tendency towards higher concentrations during the dry season for the Northeast region. Furthermore, the percentage of individual samples below the critical level found in this region was 8% during the rainy season. Mtimuni (1982) indicated that in Malawi, the percentage of cobalt-deficient forage samples (17%) was less than that in soil samples (82%) and suggested the ready availability of cobalt to plants growing on cobalt-deficient soils. Similarly, Reid and Horvath (1980) illustrated that the level of cobalt in soil does not necessarily indicate its availability to plants.

Forage copper was not different ($P > .05$) among the three regions during the rainy season. A high percentage of samples were found below the critical level suggested by McDowell et al. (1983) for forage copper (< 10 ppm), mainly in the Northeast and Southwest regions, during the rainy season. The same tendency was displayed in the dry season for these different regions; however, the percentage of deficiencies in forage copper was substantially higher for the dry season. The percentages of samples below the critical concentration in the dry season for the Northeast, Central and Southwest regions were 100, 75 and 97, respectively. With the exception of phosphorus, deficiency of copper is the most severe limitation to grazing livestock throughout extensive regions of the tropics (McDowell et al., 1983). Scaillet (1969) reported the range of forage copper (10 to 50 ppm) for different regions of Guatemala. Nevertheless, it is of importance to point out the high standard error of least square means that appears in table 17, suggesting the high variation existing among forages in copper. Therefore, copper is a micromineral which deserves special attention in formulating supplements in Guatemala, mainly in the Northeast region.

Forage manganese was not different ($P > 0.05$) among regions between seasons. Similar values were found for both seasons for each individual region. Evaluation of samples based on a dietary manganese requirement of 40 ppm (McDowell et al., 1983) indicated a number of deficient samples during both the rainy and dry seasons. Of all samples analyzed, 32 and 24% were deficient in this micromineral for the rainy and dry seasons, respectively. These data are in disagreement with the results of Scaillet (1969), who reported that, in general, the amounts of forage manganese are adequate in the different regions of Guatemala.

Forage molybdenum showed significant regional variation ($P < 0.05$) during the rainy season. Molybdenum concentrations of forages were below the toxic level of 6 ppm (McDowell et al., 1983) for all samples. Since forage sulfur was not analyzed, the ratio between copper and molybdenum was not calculated. According to Underwood (1981), copper deficiency can arise when high intakes of molybdenum and sulfur occur, coupled with normal copper intakes. However, the mean copper-to-molybdenum ratio was greater than the value of 2:1 suggested by Miltimore and Mason (1971) as the point at which a lower ratio could have conditioned copper deficiency. During the dry season, the Northeast region forages were greater ($P < 0.05$) in molybdenum than forages from the Central and Southwest. Furthermore, forage molybdenum values tended to be lower in the dry season in comparison to those in the rainy season for each of the regions.

Forage selenium was different ($P < 0.05$) among regions during the rainy season. Higher values ($P < 0.05$) were encountered for the Northeast compared to the other two regions. Individual evaluation of samples based on selenium requirements of less than 0.10 ppm (McDowell et al., 1983) indicated that the percentage of samples below the critical concentration during the rainy season in each region were as follows: Northeast, 0%; Central, 88%; and Southwest, 89%. A similar tendency was found during the dry season in which the Northeast selenium forage concentrations were higher ($P < 0.05$) than values for the Southwest region. However, no differences ($P > 0.05$) between Northeast and Central regions were found. Underwood (1977) stated that the differences in selenium concentration between accumulator and non-accumulator plants are marked, but differences between non-accumulator plants may be minor. Individual results of forage selenium concentration suggests the possibility of selenium accumulator species in the Northeast region which showed high values (1.89 ppm). In contrast, the Southwest region shows an incidence of forage selenium deficiency, with 89 and 78% of samples below critical concentration (< 0.10 ppm) for the rainy and dry seasons, respectively.

Forage zinc was higher ($P < 0.10$) in the Northeast region in comparison to the Southwest; however, no difference ($P > 0.10$) was found between the Northeast and Central regions. Individual evaluation of samples based on the dietary zinc requirement of 30 ppm (McDowell et al., 1983) indicated deficiencies of 33, 54 and 83% for the Northeast, Central and Southwest regions, respectively, during the rainy season. Similar forage zinc values were found for the Northeast and Southwest regions during the dry season; however, least square mean in the Central region was higher (43 ppm). Overall percentage of samples analyzed decreased from 61% in the rainy season to 49% during the dry season. The data from the Northeast and Southwest regions are in agreement with the statement by Underwood (1981), who reported that zinc concentration in plants decreases with advancing maturity.

Forage micromineral correlation coefficients as related to season are presented in appendix table 41. Correlation coefficients ($P < 0.05$, $r \geq |0.5|$) between forages during the rainy season were as follows: iron-cobalt ($r = 0.55$), molybdenum-selenium ($r = 0.58$), zinc-potassium ($r = 0.58$) and zinc-magnesium ($r = 0.55$). In the dry season, the correlation coefficients ($P < 0.05$, $r \geq |0.5|$) between forages were iron-cobalt ($r = 0.73$), iron-manganese ($r = 0.66$), cobalt-manganese ($r = 0.78$), manganese-sodium ($r = 0.51$), molybdenum-potassium ($r = 0.66$), selenium-potassium ($r = 0.58$), selenium-phosphorus ($r = 0.58$) and selenium-crude protein ($r = 0.56$). However, if the factor (region) has an effect on any of the forage minerals, then the estimate of the correlation previously stated could be misleading.

Animal Tissue Analyses

Blood plasma and liver micromineral concentrations as related to season, region and animal class are presented in tables 18 and 19. Results of analysis of variance are shown in appendix table 42, and number

TABLE 18. BLOOD PLASMA AND LIVER MICROMINERAL CONCENTRATIONS AS RELATED TO SEASON AND REGION

			Region										
			Northeast			Central			Southwest			Overall	
Parameter	Critical level[a]	Season	Mean[b]	S.E.[c]	% Def.	Mean	S.E.	% Def.	Mean	S.E.	% Def.	Mean	% Def.
Blood Plasma													
Cu, ppm	< 0.6	Rainy	0.45^{e}	0.09	73	0.88^{d}	0.09	5	0.99^{d}	0.07	2	0.80	23
		Dry	0.37^{e}	0.03	94	0.72^{d}	0.03	11	0.67^{d}	0.02	19	0.60	38
Se, ppm	< 0.03	Rainy	0.14^{d}	0.01	0	0.04^{e}	0.01	20	0.05^{e}	0.01	6	0.07	8
		Dry	0.13^{d}	0.01	0	0.04^{e}	0.01	26	0.05^{e}	0.01	26	0.07	19
Zn, ppm	< 0.6-0.8	Rainy	0.94^{fg}	0.06	8	1.11^{f}	0.06	3	0.91^{g}	0.05	0	0.97	3
		Dry	0.60	0.08	45	0.77	0.08	18	0.78	0.07	16	0.73	25
Liver (D.M. basis)													
Co, ppm	< 0.05	Rainy	0.48	0.04	0	0.40	0.04	0	0.45	0.03	0	0.44	0
		Dry	0.58	0.06	0	0.53	0.06	0	0.66	0.05	0	0.60	0
Cu, ppm	< 75	Rainy	68^{g}	32.3	73	101^{fg}	32.2	33	168^{f}	26.4	13	120	36
		Dry	32^{e}	41.4	96	117de	41.4	48	214^{d}	33.8	17	134	48
Fe, ppm	< 180	Rainy	458^{d}	26.5	4	276^{e}	26.5	0	357de	21.7	0	363	1
		Dry	546^{d}	42.9	0	358^{e}	42.9	4	455de	35.0	0	453	1
Mn, ppm	< 6	Rainy	9.0	0.81	13	7.5	0.81	35	9.7	0.66	18	8.9	21
		Dry	13.2^{d}	0.89	0	7.7^{e}	0.89	21	8.1^{e}	0.73	26	9.5	17
Mo, ppm	> 4	Rainy	3.7^{d}	0.28	60	2.6^{e}	0.28	96	3.7^{d}	0.23	60	3.4	70
		Dry	4.3^{d}	0.23	38	3.1^{e}	0.23	100	3.3^{e}	0.19	85	3.5	76
Se, ppm	< 0.25	Rainy	2.15^{d}	0.30	0	0.40^{e}	0.30	9	0.59^{e}	0.24	13	0.98	8
		Dry	2.69^{d}	0.26	0	0.65^{e}	0.26	4	0.62^{e}	0.21	17	1.22	9
Zn, ppm	< 84	Rainy	111	5.5	0	109	5.5	8	113	4.5	3	111	4
		Dry	103	7.0	2	115	7.0	8	118	5.7	1	113	4

[a] McDowell et al. (1983).

[b] Least square means based on the following number of samples: Blood plasma - 20 samples from each farm (10 lactating cows and 10 growing animals) and Liver - 12 samples from each farm (6 lactating cows and 6 growing animals), with 4, 4 and 6 farms within Northeast, Central and Southwest regions, respectively, for each season (rainy and dry), except for selenium - 8 samples from each farm (4 lactating cows and 4 growing animals).

[c] Standard error of least square mean.

[d,e] Means among regions in a row with different superscripts differ ($P < 0.05$).

[e,f] Means among regions in a row with different superscripts differ ($P < 0.10$).

TABLE 19. BLOOD PLASMA AND LIVER MICROMINERAL CONCENTRATIONS AS RELATED TO SEASON, REGION AND ANIMAL CLASS

			Region						Animal Class					
			Northeast		Central		Southwest		Lactating			Growing		
Parameter	Critical level[a]	Season	Mean[b] Lactating	Mean[c] Growing	Mean Lactating	Mean Growing	Mean Lactating	Mean Growing	Mean[d]	S.E.[f]	% Def.	Mean[e]	S.E.[g]	% Def.
Blood Plasma														
Cu, ppm	< 0.06	Rainy	0.42	0.48	0.83	0.92	0.96	1.01	0.74	0.03	24	0.80	0.03	22
		Dry	0.36	0.38	0.71	0.74	0.66	0.67	0.58	0.01	39	0.60	0.01	37
Se, ppm	< 0.03	Rainy	0.15	0.13	0.05	0.04	0.05	0.05	0.08[h]	0.01	9	0.07[i]	0.01	8
		Dry	0.12	0.13	0.04	0.04	0.05	0.04	0.07	0.01	16	0.07	0.01	21
Zn, ppm	< 0.6-0.8	Rainy	0.95	0.93	1.04	1.17	0.85	0.97	0.95	0.03	2	1.02	0.03	4
		Dry	0.60	0.60	0.75	0.80	0.82	0.73	0.72	0.03	24	0.71	0.03	25
Liver (D.M. basis)														
Co, ppm	< 0.05	Rainy	0.51	0.44	0.41	0.40	0.44	0.45	0.45	0.02	0	0.43	0.02	0
		Dry	0.59	0.58	0.54	0.51	0.67	0.64	0.60[h]	0.01	0	0.58[i]	0.01	0
Cu, ppm	< 75	Rainy	77	59	104	97	190	146	124[j]	5.9	33	101[k]	5.9	38
		Dry	30	34	130	105	228	201	129	9.2	48	113	9.2	49
Fe, ppm	< 180	Rainy	567	340	275	276	356	357	400	27.7	0	327	27.7	2
		Dry	559	534	383	334	480	429	474[h]	16.7	1	432[i]	16.7	1
Mn, ppm	< 6	Rainy	9.2	8.8	7.0	8.1	10.3	9.0	8.8	0.55	21	8.6	0.55	21
		Dry	13.3	13.1	7.8	7.7	8.0	8.3	9.7	0.36	17	9.7	0.36	18
Mo, ppm	> 4	Rainy	3.8	3.7	2.8	2.5	3.6	3.8	3.4	0.13	73	3.3	0.13	69
		Dry	4.0	4.6	3.2	3.0	3.3	3.3	3.5	0.07	77	3.6	0.07	75
Se, ppm	< 0.25	Rainy	2.26	2.04	0.45	0.34	0.59	0.60	1.10	0.05	7	0.99	0.05	9
		Dry	2.53	2.86	0.59	0.71	0.62	0.61	1.25	0.05	11	1.39	0.05	7
Zn, ppm	84	Rainy	114	107	115	103	110	115	113	2.8	2	108	2.8	5
		Dry	107	99	118	111	117	119	114	2.6	2	110	2.6	5

[a] McDowell et al. (1983).

[b,c] Least square means based on the following number of samples: Blood plasma - 10 samples from lactating cows and 10 from growing animals from each farm, and Liver - 6 samples from lactating cows and 6 from growing animals from each farm, with 4, 4 and 6 farms within Northeast, Central and Southwest regions, respectively, for each season (rainy and dry); except for selenium - 4 lactating and 4 growing animals from each farm.

[d,e] Least square means based on the following number of samples: Blood plasma - 140 samples from lactating cows and 140 from growing animals, and Liver - 84 samples from lactating cows and 84 from growing animals, for each season (rainy and dry); except for selenium - 56 samples from lactating cows and 56 from growing animals for each season.

[f,g] Standard error of least square mean.

[h,i] Means between animal classes in a row with different superscripts differ ($P < 0.10$).

[j,k] Means between animal classes in a row with different superscripts differ ($P < 0.05$).

of deficient micromineral samples are presented in appendix tables 43 and 44.

Blood plasma

Plasma copper was different ($P < 0.05$) among regions during the rainy season. However, no difference ($P > 0.05$) between animal classes was found for the same season. The Central and Southwest regions had higher ($P < 0.05$) plasma copper in comparison to the Northeast. Individual evaluation of samples based on 0.6 ppm plasma copper (McDowell et al., 1983) indicated that the percentages of samples below critical concentration for the Northeast, Central and Southwest regions were 73, 5 and 2, respectively. Differences ($P < 0.05$) in plasma copper were found among regions during the dry season. The higher ($P < 0.05$) values were found for the Central and Southwest regions and the lowest for the Northeast (0.37 ppm). No difference ($P > 0.05$) in plasma copper was encountered between lactating cows and growing animals. The percentages of samples below critical concentration for plasma copper (< 0.60 ppm) suggested by McDowell et al. (1983) during the dry season for each of the regions were 94 (Northeast), 11 (Central) and 19 (Southwest). Of all samples analyzed, 38% were deficient. It is of importance to point out that forage, plasma and liver copper were extremely deficient in the Northeast region; for this reason, the element deserves special attention in formulating mineral supplements for that particular region.

In the rainy season, differences ($P < 0.05$) were found among regions for blood plasma selenium; the Northeast region had higher selenium levels. The percentage of total samples below critical concentration for blood selenium (< 0.03 ppm) according to McDowell et al. (1983) for the Northeast, Central and Southwest regions were 0, 20 and 6, respectively, for the rainy season. Lactating cows had higher ($P < 0.10$) plasma selenium levels than growing animals during the same season. A similar trend was observed for blood plasma selenium during the dry season. The Northeast region had a higher ($P < 0.05$) concentration in contrast to the Central and Southwest regions. However, no difference ($P > 0.05$) was found between animal classes. Of all blood plasma selenium samples analyzed during the dry season, 19% were deficient. Plasma selenium data are in agreement with the results for forage selenium in the Northeast region. Forage selenium was found to be relatively high in the Northeast region, and blood selenium was higher than the critical level of 0.03 ppm suggested by McDowell et al. (1983).

Mean plasma zinc values were higher ($P < 0.10$) in the Central region than in the southwest region during the rainy season. Individual evaluation of samples indicated that percentage of samples below critical concentration (< 0.6-0.8 ppm) according to McDowell et al. (1983) were 8, 2 and 0, respectively, for the Northeast, Central and Southwest regions, respectively. No difference ($P > 0.05$) in plasma zinc among the three regions were found during the dry season. However, the overall percentage of samples deficient in plasma zinc increased to 25% in the dry season. Animal class showed no difference ($P > 0.05$) in plasma zinc in either the rainy or the dry season, although the element tended to be higher in growing animals during the rainy season. Similar results were obtained by Vargas (1982) in the Eastern Plains of Colombia, who reported that none of the serum zinc samples were deficient in the rainy or dry season. Conrad (1978) indicated that serum or plasma zinc is rapidly and markedly reduced with severely deficient diets, although concentrations are not greatly influenced by marginally deficient diets.

Liver

Regional differences ($P > 0.05$) were not found in liver cobalt during either season. None of the animal liver samples were deficient in cobalt, based on a critical level for deficiency of less than 0.05 ppm liver cobalt (McDowell et al., 1983). However, in the dry season, lactating cows had higher ($P < 0.10$) liver cobalt than growing animals (0.60 vs 0.45 ppm, respectively). Recently, Mtimuni (1982) in Malawi and Vargas (1982) in Colombia investigated the mineral status of grazing cattle and reported no deficiency in liver cobalt in any of the samples analyzed.

Copper in liver samples was greater ($P < 0.10$) for the Southwest region in contrast to the Northeast in the rainy season. Mean liver copper in the Northeast region was below the critical level of 75 ppm (McDowell et al., 1983), and individual evaluation of samples for this region indicated that 73% of the samples analyzed were low. Variation ($P < 0.05$) between animal classes was observed in the rainy season for liver copper; this value was higher for lactating cows than for growing animals (124 vs 101 ppm, respectively). A similar trend was encountered in the dry season for liver copper. The Southwest region had the highest ($P < 0.05$) concentrations and the Northeast, the lowest. The percentage of samples below the critical level (< 75 ppm) suggested by McDowell et al. (1983) were 86, 48 and 17 for the Northeast, Central and Southwest regions, respectively, during the dry season. Overall percentage of deficient samples was 48% in the dry season in comparison to 36% in the rainy season, with no difference ($P > 0.05$) between animal classes found. According to Owen (1982), the liver is the central organ in copper metabolism; it removes ionic copper from blood, excretes a portion into the bile, synthesizes ceruloplasmin with another portion, and the remainder could be stored as copper in the liver. Furthermore, liver copper is reported to be the best criterion for assessing the copper status of cattle (CMN, 1973). Soil, forage, plasma and liver analyses for the dry season in the Northeast region indicated 0, 100, 94 and 96% copper deficiency, respectively. Therefore, soil does not appear to aid in the diagnosis of copper deficiencies in animals.

Regional differences ($P < 0.05$) were significant in liver iron in the rainy season; however, the values in all regions were much greater than the low level of 180 ppm suggested by McDowell et al. (1983). Therefore, the overall percentage of samples below critical level was only 1% in the rainy season and 1% in the dry season for this parameter. A similar tendency was found during the dry season, with higher ($P < 0.05$) liver iron in the Northeast region. Differences ($P < 0.10$) between animal classes were observed during the dry season, with lactating animals higher than growing animals (474 vs 432 ppm, respectively). The liver is the central point of mineral metabolism in the animal body and is thus a useful organ for the estimation of iron (Boyazoglu et al., 1972). These data, therefore, suggest that iron is not a problem for grazing cattle in the different regions of Guatemala.

During the rainy season, no differences ($P > 0.05$) were found in liver manganese among the three regions. The incidence of samples below critical concentration of 6 ppm (according to McDowell et al., 1983) for the different regions were as follows: Northeast, 13%; Central, 35%; and Southwest, 18%. Of all samples analyzed in this season, 21% were deficient. No difference ($P > 0.05$) between animal classes in liver manganese was found for either season. On the other hand, differences ($P < 0.05$) in liver manganese among regions were found in the dry season. The lower values were observed in the Central and Southwest regions. The overall percentage of deficient samples for this season was 17%. McDowell et al. (1978) concluded that manganese deficiency can best be detected when there is a combination of less than 6 ppm manganese in the liver and less than 20 to 40 ppm in the diet.

Liver molybdenum was different ($P < 0.05$) among regions during the rainy season; however, no difference ($P > 0.05$) between animal classes was found. Mean liver molybdenum concentrations for each of the regions were below the 4 ppm suggested as dietary excess (McDowell et al., 1983) in the rainy season. During the dry season, a higher ($P < 0.05$) liver molybdenum value was found in the Northeast region, higher than 4 ppm. The 62 % of liver samples in the Northeast region above the 4 ppm level suggests the negative interrelationship between copper and molybdenum which could exist in the region. Therefore, the low copper content found in the Northeast region can be explained; however, forages showed low concentrations of molybdenum in that specific region.

Differences ($P < 0.05$) in liver selenium among regions were found in the rainy season. A relatively high ($P < 0.05$) amount of liver selenium was found in the Northeast region (2.15 ppm) in contrast to values of 0.40 and 0.59 ppm for the Central and Southwest regions, respectively. The concentrations of liver selenium in the Northeast region (with a high value of 6.62 ppm) again suggest the possibility of selenium toxicity in the region, as was previously discussed for forage and blood plasma selenium concentrations. A similar trend was found in the dry season, in which differences ($P < 0.05$) among regions were encountered. In the Northeast region, liver selenium was higher (2.69 ppm). In contrast, a low incidence of deficiency in liver selenium in the Southwest region was observed. Of all samples analyzed in the Southwest region, 17% were deficient. No differences ($P > 0.05$) between animal classes were found for liver selenium in either the rainy or the dry season.

During both the rainy and dry seasons, liver zinc was not different ($P > 0.05$) among regions. Similarly, no variation ($P > 0.05$) between animal classes was found during either season. The overall percentage of samples below the critical level for liver zinc of 84 ppm (McDowell et al., 1983) was 4% for both the rainy and dry seasons.

Relationship of minerals

Blood plasma and liver micromineral correlation coefficients as related to season are presented in appendix table 45. Correlation coefficients ($P < 0.05$, $r \geq |0.5|$) between blood plasma values for the rainy season were present only for copper-selenium ($r = -0.63$). Similarly, during the dry season, a negative copper-selenium ($r = -0.54$) relationship existed. However, if regions have an effect on plasma copper and selenium during both seasons, then the estimates of each correlation could be misleading.

No correlation coefficients ($P < 0.05$, $r \geq |0.5|$) were found between liver values during either season. However, other degrees in the association between liver parameters are presented in appendix table 45.

Correlation coefficients between blood plasma microelements and liver microelements as related to season, region and animal class are presented in appendix table 45. Assuming region (Northeast = N, Central = C, Southwest = S) and animal class (Lactating = L, Growing = G), correlation coefficients ($P < 0.05$, $r \geq |0.5|$) between blood plasma and liver microelements, respectively, were as follows: Rainy season - NL, copper-copper (r = 0.61); NG, copper-copper (r = 0.73); NL, selenium-copper (r = -0.53); NG, zinc-selenium (r = -0.52); CG, copper-molybdenum (r = 0.53); CL, selenium-copper (r = -0.54); and CL, zinc-copper (r = -0.63); Dry season - NG, zinc-selenium (r = 0.56); CG, copper-iron (r = 0.54); CL, selenium-zinc (r = 0.58); CL, selenium-selenium (r = 0.60); CG, selenium-copper (r = 0.61); CL, zinc-cobalt (r = 0.50); and SL, selenium-selenium (r = 0.74).

Summary and Conclusions

A study was conducted to determine the micromineral status of cattle of three producing regions in Guatemala and to compare animal classes (pregnant-lactating cows and growing steers). Soil, forage, blood and liver samples were collected at four, four and six farms within the Northeast, Central and Southwest regions, respectively, for each season. Sampling periods corresponded to the middle of the rainy season (July-August, 1980) and the middle of the dry season (February-March, 1982). Percentages of nutrient concentrations below critical levels (in parentheses) and suggestive of deficiency for Northeast, Central and Southwest regions, respectively, for the rainy season were as follows: Soil (ppm) - iron (2.5) 0, 8, 6; copper (0.3) 8, 33, 0; manganese (5) 0, 25, 6; zinc (1) 0, 8, 0; Forage (ppm) - iron (30) 0, 0, 0; cobalt (0.1) 8, 0, 3; copper (10) 63, 50, 61; manganese (40) 8, 38, 44; selenium (0.1) 0, 88, 89; zinc (30) 33, 54, 83; Blood plasma (ppm) - copper (0.6) 73, 5, 2; selenium (0.03) 0, 20, 6; zinc (0.6-0.8) 8, 3, 0; Liver (ppm) - cobalt (0.05) 0, 0, 0; copper (75) 73, 33, 13; iron (180) 4, 0, 0; manganese (6) 13, 35, 18; selenium (0.25) 0, 9, 13; zinc (84) 0, 8, 3. In the dry season, the percentages were as follows: Soil (ppm) - iron (2.5)

0, 33, 11; copper (0.3) 0, 33, 17; manganese (5) 0, 17, 0; zinc (1) 0, 17, 0; Forage (ppm) - iron (30) 0, 0, 0; cobalt (0.1) 4, 0, 0; copper (10) 100, 75, 97; manganese (40) 13, 29, 28; selenium (0.1) 4, 50, 78; zinc (30) 33, 38, 67; Blood plasma (ppm) - copper (0.6) 94, 11, 19; selenium (0.03) 0, 26, 26; zinc (0.6-0.8) 45, 18, 16; Liver (ppm) - cobalt (0.05) 0, 0, 0; copper (75) 96, 48, 17; iron (180) 0, 4, 0; manganese (6) 0, 21, 26; selenium (0.25) 0, 4, 17; and zinc (84) 2, 8, 1. Differences ($P < 0.10$) between lactating cows and growing animals were found in blood selenium in the rainy season and copper in liver ($P < 0.05$). During the dry season, liver cobalt and iron were different ($P < 0.10$) between animal classes. On the basis of the analyses, nutrients most likely deficient for each region were as follows: Northeast - severe copper, aggravated in some instances by excess molybdenum; Central - copper, manganese and selenium; Southwest - manganese and selenium. Some degree of selenium toxicity was found in the Northeast region.

CHAPTER VI
MINERAL COMPOSITION OF VARIOUS FORAGES IN GUATEMALA AND THEIR RELATIONSHIP TO SOIL CHEMISTRY

Introduction

The mineral composition of forages varies according to factors such as plant age, soil, fertilization practice, species, variety, season and grazing pressure (Gomide, 1978).

Of the total mineral concentration in soils, only a fraction is taken up by plants (Lindsay, 1972). However, little relationship has been reported between soil chemistry and mineral composition of native vegetation and farm crops (Reid and Horvath, 1980). Furthermore, mineral interactions between soil, plants and animals in Latin American countries have received little attention (Sousa, 1978). Results from Brazil indicated that correlations between soil and forage minerals were low and, in other cases, nonexistent (Sousa, 1978; Conrad et al., 1980).

The purpose of this chapter is to evaluate the mineral status of three cattle-producing regions in Guatemala in relation to composition of different forage species. In addition, the relationship between soil chemistry and the mineral composition of forages in the same regions was studied.

Materials and Methods

Soil and forage samples were collected from different farms within three regions of Guatemala during the rainy and dry seasons. Collections were made at four, four and six farms within the Northeast, Central and Southwest regions, respectively, for each season. Sampling periods corresponded to the middle of the rainy season (July-August, 1980) and the middle of the dry season (February-March, 1982). A total of 42 soil and 84 forage samples were obtained for each of the sampling periods.

Soil and forage samples were collected at the same site. The depth of the soil sample was similar to the length of the majority of the forage root systems (20 cm).

Each of the three composite soil samples for each farm came from 20 to 25 samples. The soil sampling technique used was described by Bahia (1978). Although soil samples collected during the two seasons did not come from the exact same spot, they came from the same grazing area of the farm. Soil samples were analyzed according to the procedures used by the IFAS extension soil testing laboratory in Gainesville, Florida (Mitchell and Rhue, 1979). The soil samples were analyzed for organic matter, pH, soluble salts, aluminum, calcium, potassium, magnesium, sodium, phosphorus, iron, copper, manganese and zinc. Minerals were extracted from soils using the Mehlich I extraction solution method (0.05 N HCl + 0.025 N H_2SO_4), and the soil mineral concentrations were determined by atomic absorption spectrophotometry (Perkin-Elmer, 1973).

Six composites of the major species of unfertilized forage samples from each farm were collected during each of the sampling periods. Forage samples were processed and analyzed for mineral content according to methods described by Fick et al. (1979). Calcium, potassium, magnesium, sodium, iron, copper, manganese and zinc were analyzed by atomic absorption (Perkin-Elmer, 1980). An atomic absorption spectrophotometer equipped with a graphite furnace and D_2 corrector (Perkin-Elmer Model 503) was used to determine forage cobalt and molybdenum. Phosphorus was determined by the colorimetric method described by Harris and Popat

(1954) and included by Fick et al. (1979) as a method for plant phosphorus determination. Selenium analyses of forages were carried out using the fluorometric technique described by Whetter and Ullrey (1978). Finally, crude protein concentrations in forages were determined by measuring total nitrogen, following the method of Technicon Industrial Systems (1978).

The data from each season were analyzed separately and statistically analyzed using a nested design model with proportional subclass numbers (Snedecor and Cochran, 1973); however, balance sampling was obtained. Data were analyzed by the General Linear Model procedures of the Statistical Analysis System (SAS Institute, Inc., 1982) in order to detect effects among regions. Nevertheless, the analysis of the forage data did not use species as a variable. Finally, the correlation between soil and forage responses were estimated.

Results and Discussion

Results of mineral and crude protein composition of forage species collected in each season are presented in appendix tables 47 and 48.

Forage Species

Differences ($P < 0.05$) for certain forage mineral concentrations among three cattle-producing regions of Guatemala are presented in Chapters IV and V.

Mineral and crude protein concentrations of forage species collected during the rainy and dry seasons (appendix tables 47 and 48) tended to differ. However, these differences were not statistically analyzed because the analysis of forage data did not use species as a variable. This was because the distribution of the observations over the fifteen species was quite limited. In addition, due to the limited number of species which occurred in more than one region, there is probably a high correlation between regions and farms within region with the species effects. Therefore, in this situation it would be very difficult to obtain meaningful estimates of the effects. Only overall means and standard deviations for each forage specie in each season are reported.

Gomide (1978), in Brazil, indicated differences in mineral composition among forage species. He suggested that it is necessary to make comparisons referring to the species studied in the same experiment to prevent the superimposing of effects of other factors like soil type, fertilization levels and management.

Grazing livestock depend almost entirely upon forages to meet their mineral requirements (McDowell et al., 1981). However, many forage species do not meet mineral requirements. Therefore, mineral supplementation, apart from common salt, is needed in tropical countries.

The present information about the mean mineral composition of forage species could be of some assistance to mineral manufacturers, research specialists, farmers and others concerned with formulating mineral supplements for grazing livestock.

High levels of phosphorus and crude protein, two of the most limiting nutrients for grazing livestock, are presented for Pennisetum clandestinum (Kikuyu grass) in appendix table 47. Phosphorus values of 0.40 and 0.31% for the rainy and dry seasons, respectively, are concentrations which are higher than the critical level (< 0.25%) suggested by McDowell et al. (1983). However, this species is only adapted to high altitude areas with high rainfall, which corresponds to the Central region.

In contrast, two species with low phosphorus and protein concentrations during the dry season were Andropogon gayanus and Panicum maximum.

Mean phosphorus and protein concentrations were below suggested critical levels (McDowell et al., 1983).

Mean forage mineral and crude protein concentrations by species compared to critical levels and related to season are shown in appendix table 49. The number of different species collected were 14 and 13 for the rainy and dry season, respectively.

Mean calcium concentrations among forage species ranged from 0.22 to 0.52% during the rainy season. However, this range tended to be higher during the dry season. The percentages of mean species below the suggested critical level of 0.3% calcium (McDowell et al., 1983) were 14 and 69 for the rainy and dry season, respectively.

The percentages of species below the potassium critical concentration (< 0.8%) suggested by McDowell et al. (1983) were low (0% during the dry season and 8% during the rainy season). Of all species analyzed, only Hyparrhenia rufa was deficient in potassium during the dry season. Similar results were found by Mtimuni (1982) in Malawi, where the only specie found to be deficient in potassium was Hyparrhenia spp (0.49%).

Mean magnesium, sodium and phosphorus concentration ranges among forage species during the rainy season were as follows: magnesium, 0.11 to 0.36%; sodium, 0.03 to 0.22%; and phosphorus, 0.14 to 0.40%. Similarly, for the dry season, the concentration ranges were magnesium, 0.09 to 0.36%; sodium, 0.01 to 0.10%; and phosphorus, 0.09 to 0.47%.

Of all species analyzed, only four tended to be deficient in magnesium (< 0.2%) according to McDowell et al. (1983) during the rainy season. These were Andropogon spp, Cynodon plechtostachyum, Panicum maximum, Pennisetum purpureum and Digitaria decumbens. However, during the dry season, one-half of the species were below the critical concentration.

Forage species deficient in sodium, below the suggested critical level of 0.06% (McDowell et al., 1983) were found during the rainy (36%) and dry seasons (77%). These data are in agreement with the study by Flores et al. (1978) on the Pacific coast (Retalhuleu) of Guatemala in which 75% of forages were found below the critical concentration of sodium and magnesium.

Pennisteum clandestinum and Pennisetum purpureum were two species with high levels of phosphorus (0.40 and 0.35%) during the rainy season. The percentages of species below the critical concentration of 0.25% (McDowell et al., 1983) were 50 and 54% for the rainy and dry season, respectively. Mtimuni (1982) reported mean phosphorus concentration for Hyparrhenia spp (0.07%) and Digitaria spp (0.23%) in Malawi. These results are in agreement with the present evaluation, in which mean phosphorus concentrations for Hyparrhenia rufa and Digitaria decumbens during the rainy season were 0.14 and 0.23%, respectively. This suggests the effect of specie on the mineral concentration of forages.

Among the microelements, a high percentage of species were below the critical levels for copper, manganese, selenium and zinc. Mean copper concentration ranged among forage species from 2 to 160 ppm during the rainy season and from 2 to 37 ppm in the dry season. The percentage of species below the suggested critical concentration of 10 ppm (McDowell et al., 1983) was high for both seasons, with the percentage higher in the dry season (43 vs 92%). It is of importance to note that Zea mays (appendix table 48) was the specie with the highest amount of copper and the lowest in molybdenum during the rainy season. Flores et al. (1978) stated that 100% of forages in Retalhuleu, Guatemala were deficient in copper.

The percentages of mean values for manganese, selenium and zinc below the critical levels (in parentheses) suggested by McDowell et al. (1983) during the rainy season were as follows (ppm): manganese (< 40) 21; selenium (< 0.1) 50; and zinc (< 30) 21. Similarly, during the dry season, these were found to be 15 for manganese, 31 for selenium and 38 for zinc.

Soil-Plant Relationship

Overall mean soil and forage parameters as related to season are presented in table 20. Results of the correlation coefficients between soil and forage minerals as related to season are shown in table 21.

Mineral concentration of a plant depends to some extent on the mineral content of the soil. However, soil properties and conditions markedly affect mineral uptake and utilization by plants (Wilkinson, 1972). Several factors affect soil mineral content and availability of minerals to plants. Fleming (1973) listed some of these factors which have an effect on mineral uptake by plants such as acidity, moisture, soil temperature, season, plant species, plant variety and fertilization practices. Beeson (1978) illustrated the effect of soil pH and the synergistic and antagonistic effects of ion interactions at the root surface and reported maximum rate of cation absorption to be at pH 5 to 7.

Correlation coefficients between soil and forage minerals as related to season were divided in two types (table 21). Correlations included in parentheses are those in which the factor "region" had no effect either in soil or in the forage parameters. The other correlation coefficients in the table are those in which the factor "region" (Northeast, Central and Southwest regions) had an effect on soil or forage parameters; then the estimate of the correlation coefficient could be misleading.

TABLE 20. OVERALL MEAN SOIL AND FORAGE PARAMETERS AS RELATED TO SEASON

Soil						Forage					
	Critical level	Rainy		Dry			Critical level[a]	Rainy		Dry	
Parameter		Mean[b]	S.E.	Mean	S.E.	Parameter		Mean[c]	S.E.	Mean	S.E.
Organic matter, %		4.3	1.7	7.7	2.7						
pH		6.0	0.4	6.0	0.4						
Soluble salts, ppm		738	415	250	123						
Al, ppm		306	85	342	69						
Ca, ppm	< 71[d]	2065	464	1654	572	Ca, %	< 0.3	0.34	0.11	0.28	0.09
K, ppm	< 62[e]	321	127	304	195	K, %	< 0.8	2.2	0.7	1.4	0.4
Mg, ppm	< 30[e]	386	66	388	91	Mg, %	< 0.2	0.2	0.06	0.17	0.05
Na, ppm		42	11	28	11	Na, %	< 0.06	0.09	0.07	0.03	0.02
P, ppm	< 17[e]	13.6	11.0	6.5	7.4	P, %	< 0.25	0.26	0.09	0.23	0.06
Fe, ppm	< 2.5[f]	41	38	62	95	Fe, ppm	< 30	378	248	661	262
						Co, ppm	< 0.1	0.36	0.16	0.38	0.15
Cu, ppm	< 0.3[e]	3.0	1.7	1.8	1.0	Cu, ppm	< 10	21	28	8	15
Mn, ppm	< 5[e]	64	89	54	53	Mn, ppm	< 40	92	37	93	44
						Mo, ppm	> 6	0.94	0.77	0.59	0.37
						Se, ppm	< 0.1	0.14	0.13	0.4	0.04
Zn, ppm	< 1[e]	5.6	3.8	5.9	2.5	Zn, ppm	< 30	32	13	33	9
						C.P., %	< 7	8.8	2.1	6.4	1.1

[a] McDowell et al. (1983).

[b] Mean and standard error of the mean based on 42 samples for each season (rainy and dry).

[c] Mean and standard error of the mean based on 84 samples for each season (rainy and dry).

[d] Breland (1976).

[e] Rhue and Kidder (1983).

[f] Viets and Lindsay (1973).

TABLE 21. CORRELATION COEFFICIENTS BETWEEN SOIL AND FORAGE MINERALS AS RELATED TO SEASON[a]

		Soil												
Parameter	Season	O.M.[b]	pH	S. salts[c]	Al	Ca	K	Mg	Na	P	Fe	Cu	Mn	Zn
Forage														
Ca	Rainy	-0.10	0.05	-0.22	-0.11	-0.11	0.12	-0.18	-0.22	-0.15	0.37*	0.09	0.46**	0.11
	Dry	-0.12	-0.13	-0.06	-0.09	-0.06	-0.36	-0.05	0.09	0.20	0.13	0.11	-0.15	-0.13
K	Rainy	-0.01	0.15	-0.37*	-0.04	-0.06	-0.10	-0.04	-0.01	-0.10	0.48**	0.06	0.19	-0.02
	Dry	-0.29	-0.40	0.05	-0.33	-0.04	-0.13	0.18	0.40	0.37	0.38	0.52	0.01	-0.06
Mg	Rainy	0.03	0.04	-0.16	-0.10	-0.15	-0.04	-0.23	-0.05	-0.04	0.55**	-0.05	0.31*	0.21
	Dry	0.01	-0.51	0.05	-0.10	-0.31	-0.22	-0.18	0.10	0.02	0.34	0.27	0.07	-0.09
Na	Rainy	(-0.01)[d]	(-0.25)	(-0.05)	(0.20)	(-0.16)	(-0.30+)	(-0.16)	(-0.12)	(0.18)	0.01	(0.18)	-0.08	(-0.10)
	Dry	-0.28	-0.24	(-0.05)	(-0.24)	(-0.19)	-0.13	(-0.14)	(0.11)	0.07	0.28	0.25	(-0.15)	(0.14)
P	Rainy	(-0.17)	(0.20)	(-0.43**)	(-0.08)	(-0.07)	(-0.08)	(0.01)	(0.01)	(0.11)	0.32*	(0.43**)	0.24	(-0.01)
	Dry	-0.10	-0.43	0.24	-0.22	-0.20	0.20	0.17	0.34	0.31	0.20	0.41	0.23	-0.05
Fe	Rainy	(-0.01)	(-0.11)	(-0.29+)	(0.27+)	(-0.25)	(-0.13)	(-0.34*)	(-0.21)	(-0.08)	0.20	(-0.02)	0.53**	(-0.11)
	Dry	-0.17	-0.25	(-0.12)	(-0.14)	(-0.35)	-0.13	(-0.25)	(-0.03)	0.13	0.29	0.32	(-0.10)	(-0.25)
Co	Rainy	(-0.16)	(-0.38*)	(-0.14)	(0.25)	(-0.43**)	(-0.28+)	(-0.39**)	(-0.23)	(-0.01)	0.24	(-0.07)	0.31*	(-0.05)
	Dry	-0.05	-0.35	(-0.01)	(-0.11)	(-0.34)	-0.11	(-0.31)	(-0.01)	-0.05	0.29	0.22	(-0.01)	(-0.07)
Cu	Rainy	(-0.16)	(-0.30+)	(0.05)	(0.08)	(-0.17)	(-0.15)	(-0.09)	(-0.18)	(-0.19)	0.01	(-0.05)	0.26+	(0.06)
	Dry	0.11	-0.15	(0.53**)	(-0.07)	(-0.17)	0.51	(0.08)	(0.10)	-0.11	-0.01	-0.05	(0.77**)	(0.28)
Mn	Rainy	(-0.10)	(-0.25)	(0.11)	(0.04)	(-0.44**)	(-0.25)	(-0.32*)	(-0.20)	(-0.03)	0.52**	(-0.12)	0.29+	(0.14)
	Dry	-0.05	-0.47	(-0.01)	(-0.23)	(-0.19)	-0.14	(-0.23)	(0.04)	0.11	0.34	0.32	(-0.04)	(0.04)
Mo	Rainy	-0.32*	0.36*	-0.30+	-0.18	0.26+	-0.12	0.01	0.34*	0.20	0.15	0.10	-0.15	-0.28+
	Dry	-0.15	-0.45	-0.01	-0.14	-0.05	-0.26	-0.06	0.53	0.46	0.42	0.57	-0.13	-0.06
Se	Rainy	-0.01	0.33*	-0.24	-0.37*	0.12	-0.07	0.02	0.40**	0.13	0.40**	0.01	-0.06	-0.09
	Dry	-0.19	-0.48	0.40	-0.33	-0.22	0.14	0.12	0.33	0.17	0.39	0.58	0.46	0.14
Zn	Rainy	-0.08	0.27+	-0.32*	-0.02	-0.02	0.15	-0.03	-0.08	-0.02	0.54**	0.20	0.45*	0.15
	Dry	0.05	-0.29	(0.30)	(-0.22)	(-0.18)	0.24	(0.17)	(-0.21)	-0.21	0.05	0.07	(0.44)	(0.20)
C.P.	Rainy	-0.16	0.03	-0.27+	0.23	-0.17	0.11	-0.20	-0.32*	-0.12	0.23	0.24	0.58**	0.22
	Dry	-0.19	-0.48	0.50	-0.27	-0.34	0.17	0.16	0.43	0.24	0.28	0.34	0.38	0.13

[a] Correlation coefficients based on 42 samples in each season.

[b,c] Represents organic matter and soluble salts, respectively.

[d] Correlation coefficients in parentheses are not affected by the factor "region" (Northeast, Central and Southwest regions).

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

Therefore, when only the 66 correlations in parentheses are considered, during the rainy season the following values were found: 5 (8%) which are significant at a probability level of 0.10; 3 (4%) which are significant at a level of 0.05; and 5(8%) significant at a level of 0.01. A net of 13 (20%) were significant at some probability level and 80% were not significant. Similarly, for the dry season, 42 correlation coefficients not affected by the factor "region" were found, of which only 2 (5%) were significant at $P < 0.01$. A net 5% of correlation coefficients were significant at some probability level and 95% were not significant. Furthermore, considering only correlation coefficients ($P < 0.05$, $r \geq |0.5|$), zero correlations were encountered in the rainy season and two in the dry season (soluble soil salts - forage copper, $r = -.53$, and soil manganese-forage copper, $r = 0.77$).

The correlation coefficients for the same mineral between soil and forage included in parentheses (table 21) for the rainy season were sodium ($r = -0.12$), phosphorus ($r = 0.11$) and copper ($r = -0.05$). Similarly, during the dry season, the following were encountered: sodium ($r = 0.11$), manganese ($r = -0.04$) and zinc ($r = 0.20$). These results show high incidence of low correlation coefficients between soil and forage minerals. Therefore, soil analyses prove not to be of great value in assessing the mineral status of grazing cattle. In some instances, the literature has indicated that soil cobalt is considered by the Dutch to have good diagnostic value (CMN, 1973). When cobalt is extracted with acetic acid (2.5% v/v), more than 0.3 ppm is adequate whereas less than 0.1 ppm is considered low (Conrad, 1978). Kiatoko (1979), evaluating the mineral status of beef cattle herds from four soil order regions of Florida, found a significant correlation between soil and forage cobalt at a probability level of 0.05 ($r = 0.47$). However, forage cobalt is of great value in assessing mineral deficiencies in ruminants (Conrad, 1978; CMN, 1973).

These data are in agreement with data from Brazil (Mendes, 1977; Sousa, 1978; Conrad et al., 1980). The authors stated correlation coefficients for the same mineral between soil and forage as follows: phosphorus (r = 0.11), magnesium (r = 0.04), iron (r = 0.12), manganese (r = -0.12) and zinc (r = 0.30). This indicated that correlations between soil and plants were low or lacking. Kiatoko (1979) reported soil-forage correlation coefficients in Florida as low or nonexistent as follows: calcium (r = 0.27), magnesium (r = -0.02), sodium (r = -0.20), potassium (r = 0.06), iron (r = 0.11), molybdenum (r = 0.14), selenium (r = -0.14) and zinc (r = 0.17). Similarly, from a detailed geochemical survey in Missouri (Hemphill, 1977), little relationship was found between soil chemistry and mineral composition of native vegetation and farm crops.

The results lead to the conclusion that the soil mineral system interacts differently than the plant mineral system and that factors affecting mineral uptake by plants, previously described, play an important role in the low correlation coefficients between the soil and the plant systems. Therefore, it is difficult to single out one or two factors which could explain most of the variation. Hodgson (1963) reported the effect of pH on mineral absorption by plants, which could be modified by plant specie and by amount and form of an element in the soil, coupled with other factors.

Summary and Conclusions

A study was conducted to determine the mineral composition of different forage species in three cattle-producing regions of Guatemala and to indicate the relationship found between soil chemistry and the mineral composition of forages. Soil and forage samples were collected at the same site at four, four and six farms within the Northeast, Central and Southwest regions for each season. Sampling periods corresponded to the middle of the rainy season (July-August, 1980) and the middle of the dry season (February-March, 1982). Percentages of mean species nutrient concentrations below critical levels (in parentheses) and suggestive of deficiency for the rainy and dry seasons, respectively, were as follows: calcium ($< 0.3\%$) 14, 69; potassium ($< 0.8\%$) 0, 8; magnesium ($< 0.2\%$) 36, 50; sodium ($< 0.06\%$) 36, 77; phosphorus ($< 0.25\%$) 50, 54; iron (< 30 ppm) 0, 0; cobalt (< 0.1 ppm) 7, 0; copper (< 10 ppm) 43, 92; manganese (< 40 ppm) 21, 15; molybdenum (> 6 ppm) 0, 0; selenium (< 0.10 ppm) 50, 31; zinc (< 30 ppm) 21, 38; and crude protein ($< 7\%$) 29, 46. Based on analyses, mineral and crude protein concentrations of forage species tended to differ. Soil-forage correlation coefficients of the same mineral not affected by the factor "region" for the rainy season were sodium ($r = -0.12$), phosphorus ($r = 0.11$) and copper ($r = -0.05$). In the dry season, the correlations were sodium ($r = 0.11$), manganese ($r = -0.04$) and zinc ($r = 0.20$). Results indicate low correlation coefficients between soil and forage minerals, suggesting that soil analyses are not of great value in assessing the mineral status of grazing cattle.

CHAPTER VII
SUMMARY AND CONCLUSIONS

A study was conducted in three livestock-producing regions of Guatemala to determine the mineral status of grazing cattle by evaluating mineral concentrations in soil, plant and animal tissues. This research provides the basis for future efficient and low-cost mineral supplementation throughout the country.

Soil, forage and animal tissue samples were collected from different farms within three regions during the rainy and dry seasons. The animals were divided into two classes, pregnant-lactating cows and growing steers. Collections were made at four, four and six farms within the Northeast, Central and Southwest regions, respectively, for each season. Sampling periods corresponded to the middle of the rainy season (July-August, 1980) and the middle of the dry season (February-March, 1982). A total of 42 soil, 84 forage, 280 blood plasma, 28 bone and 280 liver biopsy samples were obtained for each of the sampling periods.

Soil samples were analyzed for organic matter, pH, soluble salts, aluminum, calcium, potassium, magnesium, sodium, phosphorus, iron, copper, manganese and zinc. Forage samples were analyzed for the same minerals as in soil (except aluminum) in addition to cobalt, molybdenum, selenium and crude protein. Blood samples were analyzed for calcium, magnesium, phosphorus, copper, selenium and zinc. Bone was analyzed for calcium, magnesium, phosphorus, ash and specific gravity. Finally, liver samples were analyzed for cobalt, copper, iron, manganese, molybdenum, selenium and zinc.

During the rainy season, not many differences ($P < 0.05$) in the soil parameter concentration among regions were found. Soils from the Northeast region were higher ($P < 0.05$) in extractable iron than Central and Southwestern soils. Soil manganese in the Southwest region was lower ($P < 0.05$) than concentrations found in the Central region. The minerals most likely to be deficient in soils in decreasing order were phosphorus, copper, manganese, potassium, iron and zinc.

In the dry season, the Northeast region was higher ($P < 0.05$) in soil extractable iron and copper. Soil organic matter and potassium were higher ($P < 0.05$) in the Central region than in the Northeast. However, soil phosphorus was lower ($P < 0.10$) in the Central region in comparison to the Northeast. Soil pH was lower ($P < 0.05$) for the Northeast than the Southwest region (5.7 vs 6.3). Soil minerals most likely to be deficient in decreasing order were phosphorus, copper, iron, potassium, manganese and zinc. Correlation coefficients between soil parameters ($P < 0.05$, $r = \pm 0.05$) of significance were for pH-calcium in the rainy ($r = 0.74$) and dry ($r = 0.68$) seasons.

Forage mineral concentration differences ($P < 0.05$) among regions during the rainy season were found for calcium, potassium, magnesium, molybdenum, selenium and zinc. Nevertheless, the overall incidence of deficiency was high for other minerals such as sodium, phosphorus and copper. In the rainy season, forages in the Northeast region were higher in calcium ($P < 0.05$), potassium ($P < 0.05$), magnesium ($P < 0.05$), molybdenum ($P < 0.05$), selenium ($P < 0.05$) and zinc ($P < 0.10$) than forages from the Southwest region. Selenium was the only element which differed ($P < 0.05$) in the Northeast and Central regions during the rainy season (0.33 vs 0.08 ppm, respectively). Similarly, forage calcium was higher ($P < 0.05$) in the Central region when compared to the concentration found in the Southwest region. Minerals most likely to be deficient in forages in the rainy season, in decreasing order, are magnesium, selenium, zinc, phosphorus, copper and sodium.

In the dry season, forage minerals in the Northeast region were higher ($P < 0.05$) in calcium, potassium, magnesium and molybdenum than forages of the Central and Southwest regions. Nevertheless, forage phosphorus ($P < 0.05$), selenium ($P < 0.05$) and zinc ($P < 0.10$) were lower in the Southwest region in comparison to values of the Northeast and Central regions. Nutrients most likely to be deficient in forages in the dry season, in decreasing order, are copper, sodium, magnesium, calcium, phosphorus, crude protein, selenium and zinc.

Based on analyses, mineral and crude protein concentrations among forage species tended to differ. Among the macroelements, a high percentage of species were deficient in magnesium, phosphorus and sodium for both seasons and in calcium in the dry season. Similarly, the critical microminerals among forage species were copper, manganese, selenium and zinc.

During the rainy season, blood plasma magnesium was the only macromineral which differed ($P < 0.05$) among regions; it was higher ($P < 0.05$) in the Northeast region than in the other two regions. Plasma copper ($P < 0.05$) and zinc ($P < 0.10$) were lower in the Northeast region than in the Southwest. However, plasma selenium was higher ($P < 0.05$) in the Northeast region than in the Central and Southwest regions in the rainy season. Severe deficiencies of copper and phosphorus were indicated in blood plasma during the rainy season in the Northeast region, having a high significance as a criterion for assessing mineral status of animals in that particular region.

In the dry season, no differences ($P > 0.05$) among regions were found for blood macrominerals. However, microminerals differed; plasma copper was higher ($P < 0.05$) in the Central and Southwest regions than in the Northeast. Nevertheless, selenium was lower ($P < 0.05$) in the Central and Southwest regions than in the Northeast region. During the same season, blood plasma minerals most likely to be deficient in the Northeast region were copper and phosphorus. The Central and Southwest regions were likely to be deficient in plasma phosphorus and selenium.

Bone parameters did not vary ($P > 0.05$) among regions during either season, with the exception of specific gravity in the rainy season. However, the incidence of deficiency below critical concentrations was high for all parameters analyzed in both seasons.

In the rainy season, liver selenium was higher ($P < 0.05$) in the Northeast region in contrast to concentrations found in the other two regions. Nevertheless, the Southwest region was higher ($P < 0.10$) in liver copper than the Northeast region. Therefore, copper is a micromineral which deserves special attention in formulating supplements in Guatemala, mainly in the Northeast region. Liver iron, molybdenum and selenium were higher ($P < 0.05$) in the Northeast region than in the Central region. Liver minerals most likely to be deficient in the rainy season for each of the regions were copper in the Northeast, and copper, manganese and selenium in the Central and Southwest regions.

During the dry season, liver iron, manganese, molybdenum and selenium were higher ($P < 0.05$) in the Northeast region than in the Central region. However, liver copper was lower ($P < 0.05$) in the Northeast than in the Southwest region. Incidence of high deficiency during the dry season was again mainly for liver copper (48%).

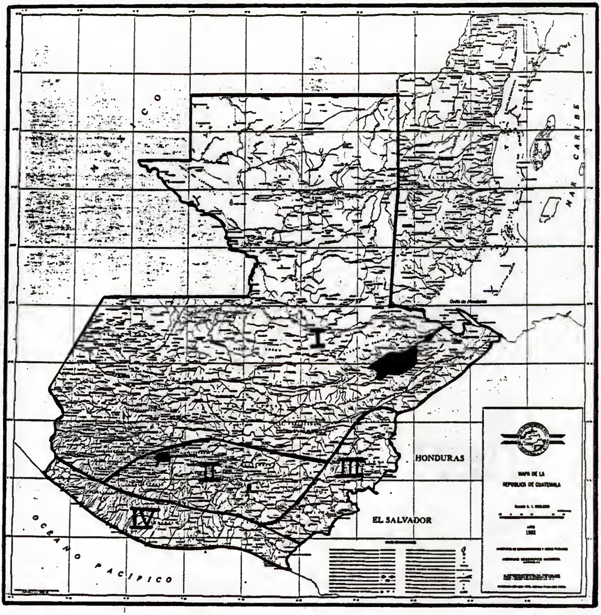
In reference to the animal class factor, plasma phosphorus was higher ($P < 0.10$) for both seasons in growing steers than in lactating cows. However, plasma calcium in the dry season was higher ($P < 0.10$) in lactating cows than in growing animals. Among the microelements, the only difference found between animal classes was in plasma selenium, which was higher ($P < 0.10$) in lactating cows than in growing animals.

Liver cobalt ($P < 0.10$) and iron ($P < 0.10$) were higher in lactating cows than in growing animals during the dry season. Similarly, liver copper was higher ($P < 0.05$) in lactating cows than in growing steers in the rainy season.

Considering only the minerals which were analyzed in the samples and taking into account the greatest value in assessing mineral deficiencies in ruminants (soil, forage, blood, bone and liver), the minerals limiting cattle production in Guatemala during the rainy season were calcium, sodium, phosphorus, copper and zinc in the Northeast region; in addition to the above minerals, manganese and selenium in the Central region; and calcium, magnesium, sodium, phosphorus, manganese and selenium in the Southwest region. In the dry season, the same minerals were limiting in each of the regions, in addition to magnesium in the Central region. Appendix figure 3 summarizes the results of the research.

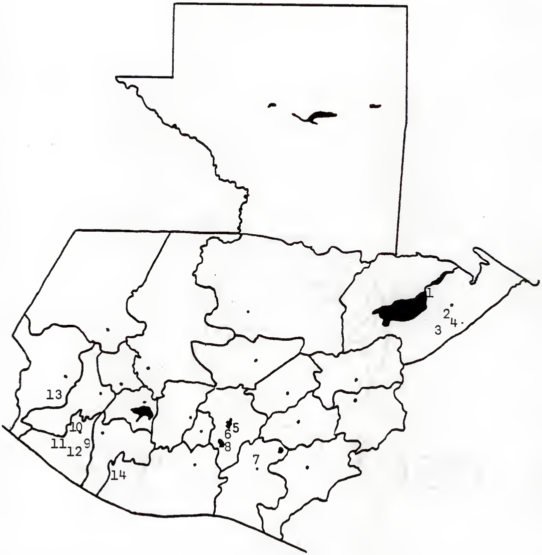
APPENDIX

APPENDIX A: FIGURES



Northern Region (I)
Central Region (II)
Eastern Region (III)
Southern Region (IV)

FIGURE 1. DISTRIBUTION OF CATTLE REGIONS IN GUATEMALA



NORTHEAST REGION

1	Las Vegas
2	Onandaga
3	Panchoy
4	Sebol

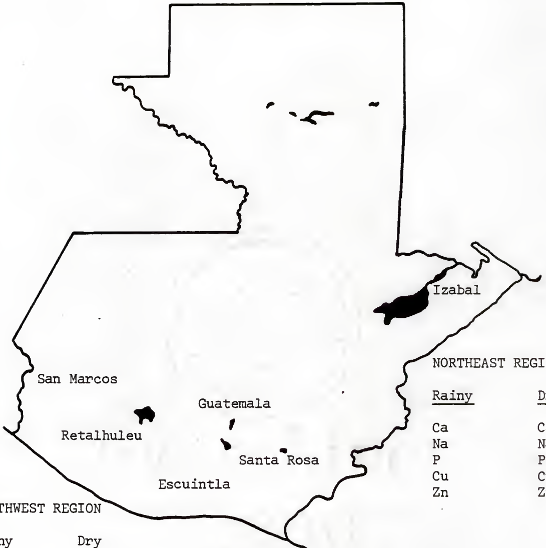
CENTRAL REGION

5	Agua Tibia
6	Concepción AT
7	El Rosario
8	Las Victorias

SOUTHWEST REGION

9	San Caralampio
10	El Danubio
11	San Juan Zapote
12	Magdalena
13	Palmira
14	Verapaz

FIGURE 2. GUATEMALA, GEOGRAPHICAL LOCATION OF SURVEYED REGIONS AND FARMS



NORTHEAST REGION

Rainy	Dry
Ca	Ca
Na	Na
P	P
Cu	Cu
Zn	Zn

SOUTHWEST REGION

Rainy	Dry
Ca	Ca
Mg	Mg
Na	Na
P	P
Mn	Mn
Se	Se

CENTRAL REGION

Rainy	Dry
Ca	Ca
Na	Mg
P	Na
Cu	P
Mn	Cu
Se	Mn
Zn	Se
	Zn

FIGURE 3. MINERALS LIMITING CATTLE PRODUCTION IN GUATEMALA BY REGION AND SEASON

APPENDIX B: TABLES

TABLE 22. FARM IDENTIFICATION IN THE NORTHEAST REGION[a]

Description[b]		Farm			
		Las Vegas	Onandaga	Panchoy	Sebol
Name of owner		Ramón Campollo	BANDEGUA	BANDEGUA	BANDEGUA
Name and address of manager		R. Ochoa Aldea Buenos Aires Izabal	M. A. Borrayo BANDEGUA Morales, Izabal	M. A. Borrayo BANDEGUA Morales, Izabal	M. A. Borrayo BANDEGUA Morales, Izabal
Location of farm					
County		Buenos Aires	Morales	Morales	Morales
Department		Izabal	Izabal	Izabal	Izabal
Latitude	(North)	15°35'	15°30'	15°30'	15°30'
Longitude	(West)	89°00	89°10	89°10	89°10
Distance from Guatemala City	(km)	270	260	260	260
Land use					
Total area	(ha)	7,200	300	1,133	850
Infrastructure	(ha)	5	15	0.70	0.70
Agronomic crops	(ha)	0	0	0	0
Natural pasture	(ha)	4,900	150	1,133	608
Improved pasture	(ha)	500	0	0	203
Forest	(ha)	1,800	100	0	0
Total cultivated	(ha)	5,400	150	1,133	811
Water	(ha)	0	0	0	45
Climate					
Type		Rain forest	Rain forest	Rain forest	Rain forest
Average temperature	(°C)	29	28	28	28
Average rainfall	(mm/year)	2,000	2,800	2,800	2,800
Dry season	(months)	Feb-Apr	Mar-Apr	Mar-Apr	Mar-Apr
Rainy season	(months)	Jun-Jan	Jun-Feb	Jun-Feb	Jun-Feb
Water data					
Source		River	River	Water well	River
Analysis	(Yes, No)	No	No	No	No

TABLE 22 - continued.

Description[b]		Farm			
		Las Vegas	Onandaga	Panchoy	Sebol
Phytography of total cultivated area					
Forest	(ha)	10	0	0	0
High plains	(ha)	0	15	0	0
Medium plains	(ha)	4,200	90	810	608
Low plains	(ha)	790	45	323	203
Flooded areas	(ha)	400	0	0	0
Pastures					
Name of predominant forages: First		Paspalum spp.	Brachiaria spp.	Paspalum spp.	Brachiaria spp.
Second		Hyparrehenia rufa	Cynodon plectostachyum	Cynodon plectostachyum	Echinochloa polystachia
Third		Echinochloa polystachia	Chloris gayana	Paspalum dilatatum	Cynodon plectostachyum
Toxic plants	(Yes, No)	Yes	Yes	Yes	Yes
Which?		Sarsa spp.	Helecho spp.	Helecho spp.	Helecho spp.
Pastures periodically burned?	(Yes, No)	No	No	No	No
Grazing system	(Rotational, continuous)	Rotational	Rotational	Rotational	Rotational
Fertilizers on pastures?	(Yes, No)	No	No	No	No
Stocking rate	(Animals/ha)	1.3	2.0	2.1	1.8
Cattle					
Principal breeds		Zebu	Zebu	Zebu	Zebu
Total cattle		8,233	310	2,375	1,486
Classes:					
Bulls		330	0	45	0
Cows		2,128	153	1,175	736
Male calves		860	0	350	250
Female calves		841	0	350	250
Males, 1-3 years		1,504	0	500	250
Females, 1-3 years		2,477	157	0	0

TABLE 22 - continued.

Description[b]		Farm			
		Las Vegas	Onandaga	Panchoy	Sebol
Fertility (calving %, 1980)	(%)	80	78	49	78
Mortality (1980)	(%)	2.5	1	5	1
Breeding season	(continual or controlled)	Continual	Artificial insemination	Controlled	Artificial insemination
Weaning age	(months)	9	8	8	8
Age heifer bred	(months)	26	22	36	22
Age steers marked	(years)	Different	2-4	4	2-4
Herd health					
Vaccination:					
Brucellosis	(Yes, No)	Yes	Yes	Yes	Yes
Hemorraghic septicemia	(Yes, No)	Yes	Yes	Yes	Yes
Anthrax	(Yes, No)	Yes	Yes	Yes	Yes
Blackleg	(Yes, No)	Yes	Yes	Yes	Yes
Parasite control:					
Internal	(Yes, No)	Yes	Yes	Yes	Yes
Gastrointestinal	(Yes, No)	Yes	Yes	Yes	Yes
Pulmonary	(Yes, No)	Yes	Yes	Yes	Yes
External	(Yes, No)	Depends	Yes	Yes	Yes

[a] The information above was provided by the farm manager during sample collection (August, 1980).

[b] Some data were derived from approximation in cases where exact data were not available.

TABLE 23. FARM IDENTIFICATION IN THE CENTRAL REGION[a]

Description[b]		Farm			
		Agua Tibia	Concepción AT	El Rosario	Las Victorias
Name of owner		IACASA	IACASA	R. Asturias	C. A. Asturias
Name and address of manager		IACASA 8 Calle 2-55Z.1 Guatemala	IACASA 8 Calle 2-55Z.1 Guatemala	R. Asturias 10 Calle 3-46Z.1 Guatemala	C. A. Asturias Las Victorias Guatemala
Location of farm					
County		Sn. José Pinula	Sn. Cat. Pinula	Villa Canales	Villa Canales
Department		Guatemala	Guatemala	Guatemala	Guatemala
Latitude	(North)	14°35'	14°38'	14°30'	14°30'
Longitude	(West)	90°20'	90°25'	90°30'	90°30'
Distance from Guatemala City	(km)	26	12	36	31
Land use					
Total area	(ha)	1,080	135	1,014	362
Infrastructure	(ha)	3	1	3	2
Agronomic crops	(ha)	175	0	20	135
Natural pasture	(ha)	25	0	254	0
Improved pasture	(ha)	280	14	720	180
Forest	(ha)	500	100	17	45
Total cultivated	(ha)	530	14	994	315
Water	(ha)				
Climate					
Type		Highlands	Highlands	Highlands	Highlands
Average temperature	(°C)	20	21	23	20
Average rainfall	(mm/year)	2,400	2,300	1,500	2,000
Dry season	(months)	Nov-Apr	Nov-Apr	Nov-May	Nov-Apr
Rainy season	(months)	May-Oct	May-Oct	Jun-Oct	May-Oct
Water data					
Source		Spring water	Water well	River	Spring water
Analysis	(Yes, No)	No	No	No	No

TABLE 23 - continued.

Description[b]		Farm			
		Agua Tibia	Concepción AT	El Rosario	Las Victorias
Phytography of total cultivated area					
Forest	(ha)	2	0	0	0
High plains	(ha)	20	0	24	20
Medium plains	(ha)	220	14	880	120
Low plains	(ha)	38	0	90	40
Flooded areas	(ha)	0	0	0	0
Pastures					
Name of predominant forages:					
First		Pennisetum clandestinum	Pennisetum clandestinum	Hyparrhenia rufa	Pennisetum clandestinum
Second		Melinis minutiflora	Melinis minutiflora	Cynodon plectostachyum	Hyparrhenia rufa
Third		Zea mays			Cynodon plectostachyum
Toxic plants?	(Yes, No)	No	No	No	No
Pastures periodically burned?	(Yes, No)	No	No	No	No
Grazing system	(Rotational, continuous)	Rotational	Rotational	Rotational	Rotational
Fertilizers on pastures?	(Yes, No)	No, Yes	No	No, Yes	No
Kinds and frequency?		Urea		Urea	
Stocking rate	(Animals/ha)	4.4	4.0	1.3	1.0
Cattle					
Principal breeds		Brangus, Angus	Brangus, Angus	Zebu	Zebu, Brown Swiss
Total cattle		1,350	130	907	118
Classes:					
Bulls		0	0	29	2
Cows		600	40	262	80
Male calves		200	0	194	6
Female calves		200	0	196	30
Males, 1-3 years		0	90	73	0
Females, 1-3 years		0	0	153	0
Fattening cattle		350	0	0	0

TABLE 23 - continued.

Description[b]		Farm			
		Agua Tibia	Concepción AT	El Rosario	Las Victorias
Fertility (calving %, 1980)	(%)	85	85	70	80
Mortality (1980)	(%)	1.5	1.0	7	2.0
Breeding season	(continual or controlled)	Artificial insemination	Artificial insemination	Controlled	Artificial insemination
Weaning age	(months)	7-8	7-8	9	8
Age heifer bred	(months)	18	18	24	24
Age steer marked	(years)	1.5-2.0	1.5-2.0	1.5-2.0	
Herd health					
Vaccination:					
Brucellosis	(Yes, No)	Yes	Yes	Yes	Yes
Hemorrhagic Septicemia	(Yes, No)	Yes	Yes	Yes	Yes
Anthrax	(Yes, No)	Yes	Yes	Yes	Yes
Blackleg	(Yes, No)	Yes	Yes	Yes	Yes
Parasite control:					
Internal	(Yes, No)	Yes	Yes	Yes	Yes
Gastrointestinal	(Yes, No)	Yes	Yes	Yes	Yes
Pulmonary	(Yes, No)	Yes	Yes	Yes	Yes
External	(Yes, No)	Yes	Yes	Yes	Yes

[a] The information above was provided by the farm manager during sample collection (August, 1980).

[b] Some data were derived from approximation in cases where exact data were not available.

TABLE 24. FARM IDENTIFICATION IN THE SOUTHWEST REGION[a]

Description[b]		Farm					
		San Caralampio	El Danubio	San Juan Zapote	Magdalena	Palmira	Verapaz
Name of owner		G. Perez	J. Aguirre Sucs.	J. Aguirre Sucs.	A.H. de Bressani	A. de Molina	IACASA
Name and address of manager		M. Hernandez San Caralampio Retalhuleu	C. Ramirez El Danubio Retalhuleu	L. de León San Juan Zapote Retalhuleu	R. Bressani 6 Calle A7-74Z.9 Guatemala	F. Cabo Palmira San Marcos	IACASA 8 Calle 2-55Z.1 Guatemala
Location of farm							
County		Sta. Cruz Muluá	Sta. Cruz Muluá	Caballo Blanco	Caballo Blanco	Pajapita	Tiquizate
Department		Retalhuleu	Retalhuleu	Retalhuleu	Retalhuleu	San Marcos	Escuintla
Latitude	(North)	14°35'	14°35'	14°29'	14°29'	14°45'	14°17'
Longitude	(West)	91°45'	91°45'	91°50'	91°50'	92°05'	91°22'
Distance from Guatemala City	(km)	185	172	225	208	240	158
Land use							
Total area	(ha)	812	493	1,834	827	824	2,037
Infrastructure	(ha)	2	7	7	3	3	10
Agronomic crops	(ha)	38	70	189	90	11	700
Natural pasture	(ha)	0	14	0	0	0	0
Improved pasture	(ha)	765	297	1,470	720	810	1,312
Forest	(ha)	0	63	126	4	0	3
Total cultivated	(ha)	803	381	1,659	810	821	2,012
Water	(ha)	7	42	42	10	0	12
Climate							
Type		Tropical	Tropical	Tropical	Tropical	Tropical	Tropical
Average temperature	(°C)	26	30	32	32	32	27
Average rainfall	(mm/year)				2,051	1,800	2,500
Dry season	(months)	Nov-Apr	Nov-Apr	Nov-May	Nov-May	Nov-Apr	Nov-Apr
Rainy season	(months)	May-Oct	May-Oct	Jun-Oct	Jun-Oct	May-Oct	May-Oct
Water data							
Source		River	River	River, lake	River	River	River
Analysis	(Yes, No)	No	No	No	No	No	No

TABLE 24 - continued.

Description[b]		Farm					
		San Caralampio	El Danubio	San Juan Zapote	Magdalena	Palmira	Verapaz
Phytography of total cultivated area							
Forest	(ha)	0	0	0	0	0	0
High plains	(ha)	10	30	59	20	20	0
Medium plains	(ha)	780	240	1,100	600	750	0
Low plains	(ha)	13	83	500	100	40	1,312
Flooded areas	(ha)	0	28	0	0	0	0
Pastures							
Name of predominant forage:							
First		Cynodon plectostachyum	Cynodon plectostachyum	Cynodon plectostachyum	Andropogon spp.	Cynodon plectostachyum	Cynodon dactylon
Second		Digitaria decumbens	Digitaria decumbens	Panicum maximum	Cynodon plectostachyum	Digitaria decumbens	Cynodon plectostachyum
Third		Echinochloa polystachya	Panicum maximum	Andropogon spp.			Pennisetum purpureum
Toxic plants?	(Yes, No)	No	No	No	Yes	Yes	No
Which?					Algodoncillo	Escobillo	
Pastures periodically burned?	(Yes, No)	No	No	No	No	No	No
Grazing system	(Rotational, continuous)	Rotational	Rotational	Rotational	Rotational	Rotational	Rotational
Fertilizers on pasture?	(Yes, No)	No	No	No	No	No	No, Yes
Kinds and frequency							Urea
Stocking rate	(Animals/ha)	2.2	2.9	2.1	3.1	2.0	4.5
Cattle							
Principal breeds		Brahman	Zebu, Simmental	Zebu	Brahman	Zebu	Brahman x Angus
Total cattle		1,700	1,092	3,208	2,226	1,628	8,300
Classes:							
Bulls		56	3	64	68	70	200
Cows		639	337	1,342	950	1,098	4,000
Male calves		341	187	517	284	105	0
Female calves		205	156	450	335	115	1,700
Males, 1-3 years		0	133	8	110	180	0
Females, 1-3 years		412	276	827	514	60	0
Fattening cattle		47	0	0	0	0	2,400

TABLE 24 - continued.

Description[b]		Farm					
		San Caralampio	El Danubio	San Juan Zapote	Magdalena	Palmira	Verapaz
Fertility (calving %, 1980)	(%)	62	65	55	65	71	85
Mortality (1980)	(%)	2	2	1	3	3.5	1.5
Breeding season	(continual or controlled)	Controlled	Artificial insemination	Controlled	Controlled	Controlled	Controlled
Weaning age	(months)	7-9	9	9	8	9	7
Age heifer bred	(months)	18-22	22-24	22-24	30	30	18-22
Age steer marked	(years)	2-2.5	No	No	No	2.5	1.5-2.0
Herd health							
Vaccination:							
Brucellosis	(Yes, No)	Yes	Yes	Yes	Yes	Yes	Yes
Hemorraghic Septicemia	(Yes, No)	Yes	Yes	Yes	Yes	Yes	Yes
Anthrax	(Yes, No)	Yes	Yes	Yes	Yes	Yes	Yes
Blackleg	(Yes, No)	Yes	Yes	Yes	Yes	Yes	Yes
Parasite control:							
Internal	(Yes, No)	Yes	Yes	Yes	Yes	Yes	Yes
Gastrointestinal	(Yes, No)	Yes	Yes	Yes	Yes	Yes	Yes
Pulmonary	(Yes, No)	Yes	Yes	Yes	Yes	Yes	Yes
External	(Yes, No)	Yes	Yes	Yes	Yes	Yes	Yes

[a] The information above was provided by the farm manager during sample collection (August, 1980).

[b] Some data were derived from approximation in cases where exact data were not available.

TABLE 25. SUMMARY OF ANALYSIS OF VARIANCE OF SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MACROMINERALS - MEAN SQUARE

Response	Region[a]	Farm/region	Residual
		Rainy season	
Organic Matter	5.2724	9.5151	2.8740
pH	0.3810	1.4704	0.1629
Soluble Salts	498643.07	621422.90	172883.14
Aluminum	43240.55	27103.43	7172.33
Calcium	394397.23	2777600.10	215635.07
Potassium	457967.21	430206.94	16109.33
Magnesium	31126.70	89501.60	4325.21
Sodium	333.23	655.62	117.90
Phosphorus	1135.09	891.44	124.19
df[b]	2	11	28
		Dry season	
Organic Matter	256.6753**	32.2437	7.1102
pH	1.3834**	0.1916	0.1345
Soluble Salts	21133.32	38254.15	15121.60
Aluminum	198661.05	94557.52	4783.71
Calcium	539910.75	515861.95	327705.12
Potassium	279212.41*	68103.05	38175.60
Magnesium	11926.70	31181.84	8305.40
Sodium	775.61	396.86	118.95
Phosphorus	226.0866+	93.8471	56.1355
df	2	11	28

[a] Test region using farm/region as an error term.

[b] Represents degrees of freedom.

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 26. NUMBER OF DEFICIENT MACROMINERALS IN SOIL SAMPLES

Region	Farm	No. of samples in each season	Ca (< 71)[a]		K (< 62)[b]		Mg (< 30)[b]		P (< 17)[b]	
			Season		Season		Season		Season	
			Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Northeast	Las Vegas	3	0	0	1	2	0	0	2	3
	Onandaga	3	0	0	0	0	0	0	3	2
	Panchoy	3	0	0	0	1	0	0	1	2
	Sebol	3	0	0	1	1	0	0	3	2
Central	Agua Tibia	3	0	0	0	0	0	0	3	3
	Concepción	3	0	0	0	0	0	0	3	3
	El Rosario	3	0	0	0	2	0	0	3	3
	Las Victorias	3	0	0	0	0	0	0	3	3
Southwest	San Caralampio	3	0	0	0	0	0	0	3	3
	El Danubio	3	0	0	0	0	0	0	3	3
	San Juan Zapote	3	0	0	0	0	0	0	3	3
	Magdalena	3	0	0	0	0	0	0	3	3
	Palmira	3	0	0	1	0	0	0	0	2
	Verapaz	3	0	0	0	0	0	0	0	1

[a] Low soil extractable mineral (ppm); Breland (1976).

[b] Low soil extractable mineral (ppm); Rhue and Kidder (1983).

TABLE 27. SOIL ORGANIC MATTER, pH, SOLUBLE SALTS AND MACROMINERAL CORRELATION COEFFICIENTS AS RELATED TO SEASON[a]

Parameter	O.M.	pH	S. salts	Al	Ca	K	Mg	Na	P
					Rainy season				
Organic matter	1.000								
pH	0.034	1.000							
Soluble salts	0.256	-0.138	1.000						
Aluminum	0.288+	-0.426**	-0.081	1.000					
Calcium	0.320*	0.740**	0.371*	-0.435**	1.000				
Potassium	0.056	0.593**	0.421**	-0.264+	0.580	1.000			
Magnesium	0.124	0.611**	0.358*	-0.521**	0.743	0.597**	1.000		
Sodium	0.158	0.598**	0.263+	-0.451**	0.614	0.398**	0.604**	1.000	
Phosphorus	-0.269+	0.252	-0.034	-0.060	0.218	0.005	0.015	0.354*	1.000
Iron	-0.070	-0.016	-0.424**	-0.064	-0.360*	-0.242	-0.333*	-0.105	-0.155
Copper	-0.379*	0.293+	-0.287+	-0.086	0.106	0.060	0.161	0.015	0.613**
Manganese	-0.185	-0.105	-0.261+	0.172	-0.309*	0.016	-0.309*	-0.359*	-0.244
Zinc	0.198	-0.112	0.361*	0.094	0.153	0.136	0.041	-0.120	-0.120
					Dry season				
Organic matter	1.000								
pH	-0.171	1.000							
Soluble salts	0.151	-0.142	1.000						
Aluminum	0.739**	-0.104	-0.112	1.000					
Calcium	0.045	0.681**	-0.045	-0.079	1.000				
Potassium	0.157	0.204	0.595**	-0.218	0.474**	1.000			
Magnesium	-0.143	0.364*	0.298+	-0.474**	0.465**	0.474**	1.000		
Sodium	-0.248	-0.192	0.352*	-0.096	-0.089	-0.061	0.071	1.000	
Phosphorus	-0.278+	0.055	0.028	-0.094	0.166	-0.190	0.098	0.523**	1.000
Iron	-0.253	-0.592**	0.066	-0.161	-0.452**	-0.228	-0.354*	0.244	-0.055
Copper	-0.471**	-0.360*	-0.008	-0.339*	-0.277+	-0.200	-0.115	0.410**	0.488**
Manganese	0.001	-0.254	0.599**	-0.216	-0.271*	0.545**	0.134	0.010	-0.176
Zinc	-0.089	0.036	0.521**	-0.278+	0.182	0.423**	0.377*	0.052	-0.075

[a] Correlation coefficients based on 42 samples in each season.

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 28. SUMMARY OF ANALYSIS OF VARIANCE OF FORAGE MACROMINERALS AND CRUDE PROTEIN - MEAN SQUARES

Response	Region[a]	Farm/region	Residual
		Rainy season	
Calcium	0.0006	0.1028	0.0243
Potassium	9.7147*	2.1140	0.5486
Magnesium	0.3161**	0.0173	0.0041
Sodium	0.0095	0.0104	0.0045
Phosphorus	0.0127	0.0445	0.0074
Crude protein	54.9440	22.4571	4.4650
df[b]	2	11	70
		Dry season	
Calcium	0.1754	0.1581	0.0213
Potassium	8.0538**	0.9290	0.1786
Magnesium	0.1709**	0.0076	0.0030
Sodium	0.0035	0.0018	0.0004
Phosphorus	0.1258*	0.0262	0.0032
Crude protein	51.3724	22.0855	1.1010
df	2	11	70

[a] Test region using farm/region as an error term.

[b] Represents degrees of freedom.

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 29. NUMBER OF DEFICIENT MACROMINERALS AND CRUDE PROTEIN IN FORAGE SAMPLES

Region	Farm	No. of samples in each season	Ca (< 0.3)[a]		K (< 0.8)[a]		Mg (< 0.2)[a]		Na (< 0.06)[a]		P (< 0.25)[a]		C.P. (< 7)[a]	
			Season		Season		Season		Season		Season		Season	
			Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Northeast	Las Vegas	6	0	2	0	2	0	2	2	5	4	3	2	2
	Onandaga	6	0	6	0	0	0	2	5	2	4	3	2	2
	Panchoy	6	0	2	0	0	2	1	5	6	4	2	4	4
	Sebol	6	3	4	0	0	2	2	1	6	1	0	2	0
Central	Agua Tibia	6	0	6	0	0	2	6	2	6	3	3	0	0
	Concepción	6	0	6	0	0	4	6	3	6	2	2	0	2
	El Rosario	6	5	4	2	6	6	5	3	6	4	6	2	6
	Las Victorias	6	2	5	0	0	3	6	6	6	6	1	2	4
Southwest	San Caralampio	6	6	4	0	0	6	6	2	5	6	6	6	4
	El Danubio	6	4	4	0	0	5	6	4	6	5	4	0	6
	San Juan Zapote	6	5	4	0	1	6	4	4	4	2	6	3	6
	Magdalena	6	0	6	0	0	6	6	5	6	3	6	2	6
	Palmira	6	6	6	4	2	6	6	2	4	6	6	6	6
	Verapaz	6	1	1	0	0	5	6	2	6	0	6	0	0

[a] Critical concentrations (%) according to McDowell et al. (1983).

TABLE 30. FORAGE MACROMINERAL AND CRUDE PROTEIN CORRELATION COEFFICIENTS AS RELATED TO SEASON[a]

Parameter	Ca	K	Mg	Na	P	C.P.
			Rainy season			
Calcium	1.000					
Potassium	0.454**	1.000				
Magnesium	0.593**	0.434**	1.000			
Sodium	-0.228*	0.138	-0.069	1.000		
Phosphorus	0.287**	0.494**	0.202+	0.061	1.000	
Iron	0.087	0.289**	0.235*	0.111	0.125	0.337**
Cobalt	0.071	0.078	0.107	0.068	0.080	0.243*
Copper	0.151	0.343**	0.094	0.393**	0.053	0.246*
Manganese	0.167	0.397**	0.477**	0.307**	0.089	0.057
Molybdenum	0.019	0.342**	0.303**	0.080	0.168	-0.079
Selenium	0.182+	0.303**	0.495**	-0.066	0.366**	0.047
Zinc	0.458**	0.584**	0.553**	0.220*	0.324**	0.483**
Crude protein	0.516**	0.487**	0.328**	-0.010	0.647**	1.000
			Dry season			
Calcium	1.000					
Potassium	0.481**	1.000				
Magnesium	0.716**	0.568**	1.000			
Sodium	-0.001	0.071	0.056	1.000		
Phosphorus	0.268*	0.725**	0.496**	0.081	1.000	
Iron	-0.035	-0.028	0.100	0.381**	-0.043	0.068
Cobalt	0.057	0.006	0.330**	0.471**	0.036	0.233*
Copper	-0.108	0.063	0.065	-0.135	0.237*	0.329**
Manganese	0.052	0.178	0.363**	0.513**	0.107	0.214+
Molybdenum	0.130	0.663**	0.386**	0.313**	0.430**	0.318**
Selenium	-0.056	0.575**	0.322**	0.054	0.577**	0.558**
Zinc	-0.044	0.232*	0.278*	-0.153	0.256*	0.364**
Crude protein	0.346**	0.610**	0.541**	0.168	0.796**	1.000

[a] Correlation coefficients based on 84 samples in each season.

+ $(P < 0.10)$.

* $(P < 0.05)$.

** $(P < 0.01)$.

TABLE 31. SUMMARY OF ANALYSIS OF VARIANCE OF BLOOD PLASMA AND BONE MACROMINERALS - MEAN SQUARES BY SEASON

Response	Region[a]	Farm/region	Class[b]	Region x class[c]	(Farm/region) x class	Residual
Blood Plasma			Rainy season			
Calcium	0.1017	0.4109	0.0051	0.3372	0.2564	0.2005
Magnesium	4.0783**	0.2321	0.2829	0.0248	0.2110	0.0523
Phosphorus	18.7438	24.9269	82.4057**	12.4479	4.7232	0.7108
df[d]	2	11	1	2	11	252
			Dry season			
Calcium	1.1320	0.8635	1.8893+	0.5365	0.4458	0.2266
Magnesium	0.1740	0.6488	0.0043	0.0152	0.1421	0.0537
Phosphorus	3.3398	21.1674	9.4723	6.0055	3.5474	0.9291
df	2	11	1	2	11	252
Bone			Rainy season			
Calcium	0.1367	2.8479				1.0321
Magnesium	0.0064	0.0048				0.0034
Phosphorus	0.2629	0.4908				0.3175
Ash	6.1979	3.3658				1.0093
Specific gravity	0.0394+	0.0136				0.0121
df	2	11				14
			Dry season			
Calcium	3.6351	4.1086				1.1171
Magnesium	0.0024	0.0048				0.0019
Phosphorus	0.1946	2.1232				0.3036
Ash	17.1113	14.4647				5.3400
Specific gravity	0.0424	0.0286				0.0154
df	2	11				14

[a] Test region using farm/region as an error term.

[b,c] Test class and region x class using (farm/region) x class as an error term.

[d] Represents degrees of freedom.

+($P < 0.10$).

*($P < 0.05$).

**($P < 0.01$).

TABLE 32. NUMBER OF DEFICIENT MACROMINERALS IN BLOOD PLASMA SAMPLES

Region	Farm	Animal class	No. of samples in each season	Ca (< 8)[a] Season Rainy	Ca (< 8)[a] Season Dry	Mg (< 2)[a] Season Rainy	Mg (< 2)[a] Season Dry	P (< 4.5)[a] Season Rainy	P (< 4.5)[a] Season Dry
Northeast	Las Vegas	Lactating	10	4	3	0	0	10	3
		Growing	10	0	2	0	0	10	3
	Onandaga	Lactating	10	3	2	0	0	0	1
		Growing	10	0	1	0	2	0	4
	Panchoy	Lactating	10	1	1	0	0	8	3
		Growing	10	0	7	0	0	2	4
	Sebol	Lactating	10	1	2	0	0	4	3
		Growing	10	2	2	0	0	0	2
Central	Agua Tibia	Lactating	10	2	0	0	0	0	0
		Growing	10	1	2	2	0	0	0
	Concepción	Lactating	10	1	1	0	0	0	0
		Growing	10	3	0	2	0	0	0
	El Rosario	Lactating	10	3	1	1	0	9	9
		Growing	10	0	3	2	0	5	10
	Las Victorias	Lactating	10	2	0	1	0	0	7
		Growing	10	0	0	2	0	0	8
Southwest	San Caralampio	Lactating	10	2	1	2	3	5	3
		Growing	10	1	2	4	0	5	0
	El Danubio	Lactating	10	2	1	1	0	7	4
		Growing	10	3	0	1	0	0	0
	San Juan Zapote	Lactating	10	0	1	1	0	6	8
		Growing	10	2	3	0	0	0	9
	Magdalena	Lactating	10	0	2	0	0	8	9
		Growing	10	1	5	3	0	3	3
	Palmira	Lactating	10	3	0	2	0	2	1
		Growing	10	1	1	1	0	1	2
	Verapaz	Lactating	10	3	1	0	2	4	0
		Growing	10	3	3	0	0	2	0

[a] Critical concentrations (mg/100 ml) according to McDowell et al. (1983).

TABLE 33. NUMBER OF DEFICIENT MACROMINERALS, ASH AND SPECIFIC GRAVITY IN BONE SAMPLES

Region	Farm	No. of samples in each season	Ca (< 24.5)[a]		P (< 11.5)[a]		Ash (< 66.8)[b]		SG (< 1.68)[c]	
			Season		Season		Season		Season	
			Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Northeast	Las Vegas	2	2	2	2	2	2	2	0	0
	Onandaga	2	2	2	2	2	2	2	0	0
	Panchoy	2	2	1	2	2	2	1	0	0
	Sebol	2	2	2	2	2	2	2	0	0
Central	Agua Tibia	2	2	1	2	2	2	1	1	0
	Concepción	2	2	2	2	2	2	2	0	0
	El Rosario	2	2	2	2	2	2	2	2	0
	Las Victorias	2	2	0	2	2	2	1	1	0
Southwest	San Caralampio	2	2	2	2	2	2	2	1	0
	El Danubio	2	2	0	2	0	2	1	2	1
	San Juan Zapote	2	2	0	2	2	2	2	2	0
	Magdalena	2	2	1	2	2	2	2	0	1
	Palmira	2	2	2	2	2	2	2	1	0
	Verapaz	2	1	0	1	2	2	0	0	0

[a] Critical concentrations (% dry, fat-free bone) according to McDowell et al. (1983).

[b] Critical bone ash (% dry, fat-free) according to McDowell et al. (1983).

[c] Critical specific gravity (g/cm^3) according to McDowell et al. (1983).

TABLE 34. BLOOD PLASMA AND BONE MACROMINERAL CORRELATION COEFFICIENTS AS RELATED TO SEASON[a]

Parameter	Blood Plasma			Bone				
	Ca	Mg	P	Ca	Mg	P	Ash	Specific Gravity
				Rainy season				
Blood Plasma								
Calcium	1.000							
Magnesium	-0.032	1.000						
Phosphorus	-0.035	-0.153**	1.000					
Copper	-0.003	-0.325**	0.036					
Selenium	0.025	0.364**	-0.024					
Zinc	0.130*	0.006	-0.292**					
				Dry season				
Calcium	1.000							
Magnesium	0.052	1.000						
Phosphorus	-0.020	-0.033	1.000					
Copper	0.131*	0.070	-0.089					
Selenium	-0.085	0.011	-0.100+					
Zinc	-0.082	0.061	0.081					
				Rainy season				
Bone								
Calcium				1.000				
Magnesium				0.392*	1.000			
Phosphorus				0.824**	0.178	1.000		
Ash				0.345+	0.012	0.353+	1.000	
Specific gravity				0.301+	0.007	0.274	0.401*	1.000
				Dry season				
Calcium				1.000				
Magnesium				0.183	1.000			
Phosphorus				0.546**	0.453*	1.000		
Ash				0.849**	-0.297	0.418*	1.000	
Specific gravity				0.487**	-0.216	0.152	0.506**	1.000

[a] Correlation coefficients based on 280 blood plasma samples and 28 bone samples in each season.

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 35. CORRELATION COEFFICIENTS BETWEEN BLOOD PLASMA MACROELEMENTS AND LIVER MICROELEMENTS AS RELATED TO SEASON, REGION AND ANIMAL CLASS[a]

Parameter by region	Animal class	Liver						
		Co	Cu	Fe	Mn	Mo	Zn	Se
Blood Plasma					Rainy Season			
Northeast								
Ca	Lactating	0.292	-0.297	0.403*	-0.144	-0.011	-0.254	-0.177
	Growing	0.064	-0.338	-0.045	-0.422*	0.134	-0.343+	-0.448+
Mg	Lactating	-0.186	0.387+	0.332	0.479*	0.099	0.129	-0.310
	Growing	0.147	-0.016	0.002	0.034	0.065	-0.313	-0.473+
P	Lactating	0.173	-0.693**	0.087	-0.339+	0.424*	-0.394+	-0.128
	Growing	0.408*	-0.713**	0.398+	-0.533**	0.324	-0.275	0.367
Central								
Ca	Lactating	0.025	-0.376+	0.383+	-0.098	0.138	0.183	0.621**
	Growing	0.269	-0.186	-0.227	-0.035	-0.004	-0.492*	0.589*
Mg	Lactating	0.004	-0.003	0.211	0.219	0.406*	0.216	-0.201
	Growing	-0.022	0.050	-0.144	-0.127	-0.142	-0.435*	-0.030
P	Lactating	0.429*	-0.786**	0.072	-0.513**	0.350+	0.331	-0.136
	Growing	0.114	-0.777**	0.383+	-0.158	0.719**	0.086	0.069
Southwest								
Ca	Lactating	0.043	-0.330*	-0.089	-0.207	0.140	-0.145	0.142
	Growing	-0.268	-0.045	-0.342*	0.040	-0.180	-0.010	0.179
Mg	Lactating	-0.450**	-0.418*	-0.351*	0.164	0.156	-0.369*	0.541**
	Growing	-0.004	-0.253	-0.151	-0.429**	0.102	-0.153	0.117
P	Lactating	-0.331*	0.027	-0.279+	-0.004	-0.050	-0.079	-0.066
	Growing	0.052	-0.180	-0.016	-0.317+	0.255	-0.230	-0.176

TABLE 35 - continued.

Parameter by region	Animal class	Liver						
		Co	Cu	Fe	Mn	Mo	Zn	Se
Blood Plasma					Dry season			
Northeast								
Ca	Lactating	0.443*	-0.024	-0.197	0.610**	-0.455*	-0.005	-0.326
	Growing	0.070	0.237	0.486*	0.140	0.408*	-0.370+	-0.138
Mg	Lactating	-0.131	0.058	-0.467*	0.056	-0.324	-0.346+	0.493+
	Growing	-0.205	-0.006	-0.101	0.251	-0.060	0.110	0.138
P	Lactating	-0.252	-0.175	0.061	0.038	-0.088	-0.101	0.236
	Growing	0.170	-0.163	0.154	0.323	0.380+	0.185	-0.039
Central								
Ca	Lactating	-0.449*	0.379+	-0.196	0.059	0.167	0.135	-0.138
	Growing	-0.110	-0.035	-0.214	-0.072	-0.082	-0.312	0.181
Mg	Lactating	0.091	0.529**	0.316	0.459*	0.019	0.268	0.131
	Growing	0.212	0.577**	0.023	-0.382+	-0.033	-0.084	0.301
P	Lactating	-0.062	-0.704**	-0.168	-0.254	0.148	-0.391+	-0.209
	Growing	0.088	-0.714**	0.233	0.108	0.549**	0.174	-0.755**
Southwest								
Ca	Lactating	0.028	0.129	0.219	0.222	0.035	-0.010	0.428*
	Growing	-0.058	0.070	-0.187	0.142	-0.317+	0.308+	0.275
Mg	Lactating	0.156	-0.039	-0.203	-0.103	-0.004	0.001	-0.544**
	Growing	0.147	0.297+	-0.020	0.100	-0.388*	-0.130	-0.480*
P	Lactating	-0.403*	-0.138	-0.231	-0.398*	-0.004	-0.050	0.250
	Growing	-0.388*	0.157	-0.280+	-0.059	-0.123	-0.186	-0.294

[a] Correlation coefficients based on the following number of samples: 12 samples from each farm (6 lactating and 6 growing), with 4, 4 and 6 farms within Northeast, Central and Southwest regions, respectively, for each season (rainy and dry); except for selenium, 8 samples from each farm (4 lactating and 4 growing).

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 36. SUMMARY OF ANALYSIS OF VARIANCE OF SOIL MICROMINERALS - MEAN SQUARES

Response	Region[a]	Farm/region	Residual
		Rainy season	
Iron	21696.94**	2034.85	1453.05
Copper	27.0357	63.8001	2.8881
Manganese	73926.40*	19635.55	7925.97
Zinc	2.9624	55.1990	14.4036
df[b]	2	11	28
		Dry season	
Iron	80080.67**	6045.52	9074.86
Copper	19.5341**	2.2816	1.0576
Manganese	17311.82	9020.74	2852.28
Zinc	17.1679	24.7189	6.3881
df	2	11	28

[a] Test region using farm/region as an error term.

[b] Represents degrees of freedom.

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 37. NUMBER OF DEFICIENT MICROMINERALS IN SOIL SAMPLES

		No. of samples in each season	Fe (< 2.5)[a]		Cu (< 0.3)[b]		Mn (< 5)[b]		Zn (< 1)[b]	
			Season		Season		Season		Season	
Region	Farm		Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Northeast	Las Vegas	3	0	0	1	0	0	0	0	0
	Onandaga	3	0	0	0	0	0	0	0	0
	Panchoy	3	0	0	0	0	0	0	0	0
	Sebol	3	0	0	0	0	0	0	0	0
Central	Agua Tibia	3	0	0	0	0	0	0	0	0
	Concepción	3	0	0	0	0	0	0	0	0
	El Rosario	3	0	3	2	3	2	1	1	2
	Las Victorias	3	1	1	2	1	1	1	0	0
Southwest	San Caralampio	3	0	0	0	2	0	0	0	0
	El Danubio	3	0	0	0	0	0	0	0	0
	San Juan Zapote	3	0	1	0	0	0	0	0	0
	Magdalena	3	0	1	0	1	0	0	0	0
	Palmira	3	0	0	0	0	0	0	0	0
	Verapaz	3	1	0	0	0	1	0	0	0

[a] Low soil extractable mineral (ppm); Viets and Lindsay (1973).

[b] Low soil extractable mineral (ppm); Rhue and Kidder (1983).

TABLE 38. SOIL MICROMINERAL CORRELATION COEFFICIENTS AS RELATED TO SEASON[a]

Parameter	Fe	Cu	Mn	Zn
		Rainy season		
Organic matter	0.070	-0.379*	-0.185	0.198
pH	-0.016	0.293+	-0.105	-0.112
Soluble salts	-0.424**	-0.287+	-0.261+	0.361*
Aluminum	-0.064	-0.086	0.172	0.094
Calcium	-0.360**	0.106	-0.309*	0.153
Potassium	-0.242	0.060	0.016	0.136
Magnesium	-0.333*	0.161	-0.309*	0.041
Sodium	-0.105	0.015	-0.359*	-0.120
Phosphorus	-0.155	0.613**	-0.244	-0.120
Iron	1.000			
Copper	-0.064	1.000		
Manganese	0.268+	-0.056	1.000	
Zinc	-0.014	-0.272+	0.182	1.000
		Dry season		
Organic matter	-0.253	-0.471**	0.001	-0.089
pH	-0.592**	-0.360*	-0.254	0.036
Soluble salts	0.066	-0.008	0.599**	0.521**
Aluminum	-0.161	-0.339*	-0.216	-0.278+
Calcium	-0.452**	-0.277+	-0.271*	0.182
Potassium	-0.228	-0.200	0.545**	0.423**
Magnesium	-0.354*	-0.115	0.134	0.377*
Sodium	0.244	0.410**	0.010	0.052
Phosphorus	-0.055	0.488**	-0.176	-0.075
Iron	1.000			
Copper	0.706**	1.000		
Manganese	0.111	0.041	1.000	
Zinc	-0.094	-0.176	0.397**	1.000

[a] Correlation coefficients based on 42 samples in each season.

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 39. SUMMARY OF ANALYSIS OF VARIANCE OF THE FORAGE MICROMINERALS - MEAN SQUARES

Response	Region[a]	Farm/region	Residual
		Rainy season	
Iron	323183.38	387761.61	61612.89
Cobalt	0.0006	0.1028	0.0243
Copper	3130.21	5842.22	761.83
Manganese	67702.01	25307.89	1382.28
Molybdenum	11.6622*	2.3415	0.5900
Selenium	0.6155**	0.0268	0.0194
Zinc	1157.51+	405.18	179.29
df[b]	2	11	70
		Dry season	
Iron	603743.55	818080.82	68751.86
Cobalt	0.1754	0.1581	0.0213
Copper	2472.85	1903.50	245.03
Manganese	60971.86	30155.33	1904.48
Molybdenum	7.2718**	0.9907	0.1335
Selenium	3.2228*	0.8179	0.0016
Zinc	2179.57	945.49	89.34
df	2	11	70

[a] Test region using farm/region as an error term.

[b] Represents degrees of freedom.

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 40. NUMBER OF DEFICIENT MICROMINERALS IN FORAGE SAMPLES

Region	Farm	No. of samples in each season	Fe (< 30)[a]		Co (< 0.1)[a]		Cu (< 10)[a]		Mn (< 40)[a]		Mo (> 6)[b]		Se (< 0.1)[a]		Zn (< 30)[a]	
			Season		Season		Season		Season		Season		Season		Season	
			Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry	Rainy	Dry
Northeast	Las Vegas	6	0	0	0	0	4	6	0	0	0	0	0	1	2	1
	Onandaga	6	0	0	0	0	3	6	0	0	0	0	0	0	0	2
	Panchoy	6	0	0	2	1	6	6	2	2	0	0	0	0	3	3
	Sebol	6	0	0	0	0	2	6	0	1	0	0	0	0	3	2
Central	Agua Tibia	6	0	0	0	0	0	0	0	0	0	0	6	0	2	0
	Concepción	6	0	0	0	0	0	6	3	5	0	0	6	0	4	0
	El Rosario	6	0	0	0	0	6	6	4	2	0	0	5	6	5	5
	Las Victorias	6	0	0	0	0	6	6	2	0	0	0	4	6	2	4
Southwest	San Caralampio	6	0	0	0	0	0	6	0	4	0	0	4	6	6	1
	El Danubio	6	0	0	0	0	4	6	1	0	0	0	6	4	5	3
	San Juan Zapote	6	0	0	0	0	2	6	6	2	0	0	4	6	6	6
	Magdalena	6	0	0	0	0	6	6	4	4	0	0	6	6	6	4
	Palmira	6	0	0	0	0	6	6	0	0	0	0	6	6	6	4
	Verapaz	6	0	0	1	0	4	5	5	0	0	0	6	0	1	6

[a] Critical concentrations (ppm) according to McDowell et al. (1983).

[b] Suggestive of an excess (ppm) according to McDowell et al. (1983).

TABLE 41. FORAGE MICROMINERAL CORRELATION COEFFICIENTS AS RELATED TO SEASON[a]

Parameter	Fe	Co	Cu	Mn	Mo	Se	Zn
				Rainy season			
Calcium	0.087	0.071	0.151	0.167	0.019	0.182+	0.458**
Potassium	0.289**	0.078	0.343**	0.397**	0.342**	0.303**	0.584**
Magnesium	0.235*	0.107	0.094	0.477**	0.303**	0.495**	0.553**
Sodium	0.111	0.068	0.393**	0.307**	0.080	-0.066	0.220*
Phosphorus	0.125	0.080	0.053	0.089	0.168	0.366**	0.324**
Iron	1.000						
Cobalt	0.552**	1.000					
Copper	0.290*	0.096	1.000				
Manganese	0.325**	0.328**	0.126	1.000			
Molybdenum	0.236*	0.054	-0.228*	0.153	1.000		
Selenium	0.096	0.065	-0.069	0.221*	0.575**	1.000	
Zinc	0.384**	0.206+	0.166	0.484**	0.146	0.207+	1.000
Crude Protein	0.337**	0.243*	0.246*	0.057	-0.079	0.047	0.482**
				Dry season			
Calcium	-0.035	0.057	-0.108	0.052	0.130	-0.056	-0.044
Potassium	-0.028	0.006	0.063	0.178	0.663**	0.575**	0.232*
Magnesium	0.100	0.330**	0.065	0.363**	0.386**	0.322**	0.278*
Sodium	0.381**	0.471**	-0.135	0.513**	0.313**	0.054	-0.153
Phosphorus	-0.043	0.036	0.237*	0.107	0.430**	0.577**	0.256*
Iron	1.000						
Cobalt	0.733**	1.000					
Copper	-0.071	-0.042	1.000				
Manganese	0.658**	0.784**	0.023	1.000			
Molybdenum	0.237*	0.286**	-0.092	0.485**	1.000		
Selenium	0.002	0.111	0.281**	0.225*	0.526**	1.000	
Zinc	0.041	0.108	0.479**	0.238*	-0.041	0.476**	1.000
Crude Protein	0.068	0.233*	0.329**	0.214+	0.318**	0.558**	0.364**

[a] Correlation coefficients based on 84 samples in each season.

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 42. SUMMARY OF ANALYSIS OF VARIANCE OF BLOOD PLASMA AND LIVER MICROMINERALS - MEAN SQUARES BY SEASON

Response	Region[a]	Farm/region	Class[b]	Region x class[c]	(Farm/region) x class	Residual
Blood Plasma			Rainy season			
Copper	7.2654**	0.5840	0.2490	0.0094	0.1430	0.0277
Selenium	0.2534**	0.0175	0.0031*	0.0019	0.006	0.0007
Zinc	0.9868+	0.2308	0.4488	0.1553	0.1577	0.0222
df[d]	2	11	1	2	11	252
			Dry season			
Copper	3.0255**	0.0735	0.0209	0.0035	0.0191	0.0160
Selenium	0.1881**	0.0073	0.0008	0.0021	0.0010	0.0009
Zinc	0.8520	0.5068	0.0264	0.1053	0.0956	0.0200
df	2	11	1	2	11	252
Liver			Rainy season			
Cobalt	0.0668	0.0661	0.0113	0.0183	0.0383	0.0185
Copper	154892+	50123	28809	5408	2969	2246
Iron	398927**	33803	160890	208436	64456	15602
Manganese	64.7103	31.6488	5.3929	23.1133	24.9918	7.0742
Molybdenum	20.2341*	3.8958	0.2430	0.8147	1.3337	0.9189
Zinc	162	1424	409	1233	668	324
df	2	11	1	2	11	140
Selenium	31.0479**	2.7893	0.2313	0.1302	0.1242	0.4080
df	2	11	1	2	11	84
			Dry season			
Cobalt	0.2455	0.1695	0.0312*	0.0007	0.0067	0.0160
Copper	487473*	82401	12985	3697	7129	4450
Iron	425447*	88225	76245+	2874	23381	18927
Manganese	470.9841**	38.0178	0.1371	1.0208	10.9574	4.1283
Molybdenum	19.2106**	2.6057	0.5071	2.3258*	0.4439	0.6524
Zinc	3254	2356	550	444	549	431
df	2	11	1	2	11	140
Selenium	48.8129**	2.1376	0.4276	0.2700	0.1485	0.1631
df	2	11	1	2	11	84

[a] Test region using farm/region as an error term.

[b,c] Test class and region x class using (farm/region) x class as an error term.

[d] Represents degrees of freedom.

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 43. NUMBER OF DEFICIENT MICROMINERALS IN BLOOD PLASMA SAMPLES

				Cu (<0.6)[a]		Se (< 0.03)[a]		Zn (<0.6-0.8)[a]	
				Season		Season		Season	
Region	Farm	Animal class	No. of samples in each season	Rainy	Dry	Rainy	Dry	Rainy	Dry
Northeast	Las Vegas	Lactating	10	0	10	0	0	0	5
		Growing	10	0	10	0	0	0	2
	Onandaga	Lactating	10	9	10	0	0	0	3
		Growing	10	10	7	0	0	0	6
	Panchoy	Lactating	10	10	10	0	0	0	1
		Growing	10	10	10	0	0	0	2
	Sebol	Lactating	10	9	9	0	0	1	8
		Growing	10	10	9	0	0	5	9
Central	Agua Tibia	Lactating	10	0	2	1	4	0	0
		Growing	10	0	2	5	6	0	0
	Concepción	Lactating	10	0	0	1	4	0	0
		Growing	10	0	2	1	7	0	0
	El Rosario	Lactating	10	0	0	5	0	2	0
		Growing	10	0	1	3	0	0	3
	Las Victorias	Lactating	10	4	2	0	0	0	10
		Growing	10	0	0	0	0	0	1
Southwest	San Caralampio	Lactating	10	0	0	1	6	0	5
		Growing	10	0	0	0	9	0	3
	El Danubio	Lactating	10	0	3	4	7	0	1
		Growing	10	0	1	2	7	0	3
	San Juan Zapote	Lactating	10	0	0	0	0	0	1
		Growing	10	1	4	0	0	0	2
	Magdalena	Lactating	10	0	3	0	0	0	0
		Growing	10	0	1	0	0	0	0
	Palmira	Lactating	10	1	0	0	1	0	0
		Growing	10	0	0	0	0	0	2
	Verapaz	Lactating	10	0	6	0	0	0	0
		Growing	10	0	5	0	1	0	2

[a] Critical concentrations (ppm) according to McDowell et al. (1983).

TABLE 44. NUMBER OF DEFICIENT MICROMINERALS IN LIVER SAMPLES

Region	Farm	Animal class	No. of samples in each season	Co (< 0.05)^{a} Season Rainy	Co (< 0.05)^{a} Season Dry	Cu (< 75)^{a} Season Rainy	Cu (< 75)^{a} Season Dry	Fe (< 180)^{a} Season Rainy	Fe (< 180)^{a} Season Dry	Mn (< 6)^{a} Season Rainy	Mn (< 6)^{a} Season Dry	Mo (> 4)^{b} Season Rainy	Mo (> 4)^{b} Season Dry	Zn (< 84)^{a} Season Rainy	Zn (< 84)^{a} Season Dry	No. of samples in each season	Se (< 0.25)^{a} Season Rainy	Se (< 0.25)^{a} Season Dry
Northeast	Las Vegas	Lactating	6	0	0	0	6	0	0	1	0	5	3	0	0	4	0	0
		Growing	6	0	0	0	6	0	0	0	0	6	2	0	0	4	0	0
	Onandaga	Lactating	6	0	0	6	6	0	0	1	0	0	0	0	0	4	0	0
		Growing	6	0	0	6	6	1	0	1	0	0	0	0	0	4	0	0
	Panchoy	Lactating	6	0	0	6	6	0	0	1	0	2	4	0	0	4	0	0
		Growing	6	0	0	6	6	1	0	0	0	4	2	0	0	4	0	0
	Sebol	Lactating	6	0	0	6	5	0	0	2	0	6	4	0	0	4	0	0
		Growing	6	0	0	5	5	0	0	0	0	6	3	0	1	4	0	0
Central	Agua Tibia	Lactating	6	0	0	4	5	0	0	4	3	5	6	1	0	4	0	2
		Growing	6	0	0	6	6	0	0	3	2	6	6	0	0	4	1	0
	Concepción	Lactating	6	0	0	0	6	0	0	2	0	6	6	0	0	4	1	0
		Growing	6	0	0	1	5	0	0	1	0	6	6	0	1	4	1	0
	El Rosario	Lactating	6	0	0	0	0	0	0	1	0	5	6	0	0	4	0	0
		Growing	6	0	0	0	1	0	1	0	3	6	6	0	1	4	0	0
	Las Victorias	Lactating	6	0	0	3	0	0	1	3	2	6	6	0	1	4	0	0
		Growing	6	0	0	2	0	0	0	3	0	6	6	3	1	4	0	0
Southwest	San Caralampio	Lactating	6	0	0	0	0	0	0	2	1	6	6	0	0	4	0	0
		Growing	6	0	0	0	0	0	0	0	2	5	6	0	0	4	0	0
	El Danubio	Lactating	6	0	0	0	0	0	0	0	1	4	6	0	1	4	3	4
		Growing	6	0	0	0	0	0	0	2	2	4	6	0	0	4	3	4
	San Juan Zapote	Lactating	6	0	0	0	0	0	0	0	0	4	4	0	0	4	0	0
		Growing	6	0	0	1	0	0	0	1	0	0	6	0	0	4	0	0
	Magdalena	Lactating	6	0	0	1	0	0	0	0	0	4	6	0	0	4	0	0
		Growing	6	0	0	2	1	0	0	0	1	2	6	0	0	4	0	0
	Palmira	Lactating	6	0	0	0	0	0	0	1	3	4	5	0	0	4	0	0
		Growing	6	0	0	0	0	0	0	1	0	5	6	0	0	4	0	0
	Verapaz	Lactating	6	0	0	2	6	0	0	0	4	3	2	1	0	4	0	0
		Growing	6	0	0	3	5	0	0	6	5	2	2	1	0	4	0	0

[a] Critical concentrations (ppm) according to McDowell et al. (1983).

[b] Suggestive of an excess (ppm) according to McDowell et al. (1983).

TABLE 45. BLOOD PLASMA AND LIVER MICROMINERAL CORRELATION COEFFICIENTS AS RELATED TO SEASON[a]

Parameter	Blood Plasma			Liver					
	Cu	Se	Zn	Fe	Co	Cu	Mn	Mo	Zn
				Rainy season					
Blood Plasma									
Calcium	-0.003	0.025	0.130*						
Magnesium	-0.325**	0.364**	0.006						
Phosphorus	0.036	-0.024	0.292**						
Copper	1.000								
Selenium	-0.634**	1.000							
Zinc	0.042	-0.058	1.000						
				Dry season					
Calcium	0.131*	-0.085	0.082						
Magnesium	0.070	0.011	0.061						
Phosphorus	-0.089	-0.100+	0.081						
Copper	1.000								
Selenium	-0.537**	1.000							
Zinc	0.303**	-0.254**	1.000						
				Rainy season					
Liver									
Iron				1.000					
Cobalt				0.408**	1.000				
Copper				-0.104	0.081	1.000			
Manganese				0.148+	0.022	0.255**	1.000		
Molybdenum				0.278**	0.112	-0.193*	0.017	1.000	
Zinc				0.174*	0.212**	0.278**	0.132+	0.022	1.000
				Dry season					
Iron				1.000					
Cobalt				0.246**	1.000				
Copper				0.002	0.411**	1.000			
Manganese				0.249**	0.144+	-0.183*	1.000		
Molybdenum				0.290**	-0.060	-0.309**	0.229**	1.000	
Zinc				0.203**	0.135+	0.327**	-0.139+	-0.152*	1.000

[a] Correlation coefficients based on 280 blood plasma samples and 168 liver samples in each season.

+(P < 0.10).

*(P < 0.05).

**(P < 0.01).

TABLE 46. CORRELATION COEFFICIENTS BETWEEN BLOOD PLASMA MICROELEMENTS AND LIVER MICROELEMENTS AS RELATED TO SEASON, REGION AND ANIMAL CLASS[a]

Parameter by region	Animal class	Liver						
		Co	Cu	Fe	Mn	Mo	Zn	Se
Blood Plasma					Rainy season			
Northeast								
Cu	Lactating	-0.210	0.611**	-0.263	0.143	-0.418*	0.228	-0.219
	Growing	-0.402*	0.734**	-0.476*	0.499*	-0.440*	0.304	-0.298
Se	Lactating	0.134	-0.527**	0.488*	-0.049	0.263	-0.540**	0.352
	Growing	0.146	-0.694**	0.190	-0.598**	0.335	-0.243	0.469+
Zn	Lactating	0.023	-0.010	0.257	0.055	0.153	-0.168	-0.247
	Growing	-0.410*	-0.027	-0.283	-0.150	0.097	-0.349+	-0.523*
Central								
Cu	Lactating	-0.416*	-0.170	0.190	-0.150	0.193	-0.044	0.127
	Growing	0.130	-0.536**	0.375+	-0.280	0.529**	0.092	-0.380
Se	Lactating	0.295	-0.536**	-0.132	-0.436*	-0.083	-0.214	0.015
	Growing	0.499*	0.099	-0.243	-0.236	0.113	-0.243	0.089
Zn	Lactating	0.353+	-0.628**	-0.195	-0.264	0.004	0.339	-0.254
	Growing	-0.184	0.046	0.285	0.027	-0.279	0.103	0.333
Southwest								
Cu	Lactating	-0.442**	-0.472**	-0.156	0.171	0.152	-0.157	0.151
	Growing	-0.323+	-0.178	-0.233	-0.371*	0.101	-0.233	0.493*
Se	Lactating	-0.002	0.023	0.060	0.130	-0.031	0.207	0.101
	Growing	-0.234	-0.109	-0.039	-0.093	0.207	-0.172	0.231
Zn	Lactating	0.124	0.086	-0.088	-0.043	-0.188	0.248	-0.244
	Growing	-0.068	0.111	-0.102	-0.323+	-0.082	0.226	-0.171
Blood Plasma					Dry season			
Northeast								
Cu	Lactating	0.077	0.172	-0.220	-0.391+	0.439*	-0.185	0.131
	Growing	-0.186	0.193	0.170	-0.421*	0.202	0.024	-0.254
Se	Lactating	-0.090	-0.258	-0.315	0.013	0.067	0.007	-0.056
	Growing	0.117	-0.189	0.166	-0.053	0.099	0.296	-0.397
Zn	Lactating	-0.387+	-0.218	-0.067	-0.342	0.164	-0.248	0.541*
	Growing	-0.407*	-0.221	0.108	-0.358+	0.238	0.481*	0.560*
Central								
Cu	Lactating	0.333	0.187	0.347+	-0.302	-0.061	0.135	-0.069
	Growing	0.184	-0.163	0.539**	0.161	0.042	0.250	0.357
Se	Lactating	-0.050	0.405*	0.413*	0.075	0.018	0.575**	0.599*
	Growing	0.020	0.610**	0.048	-0.323	-0.184	0.078	0.329
Zn	Lactating	0.502*	0.050	0.203	0.018	-0.102	0.401+	-0.070
	Growing	0.385+	-0.489*	0.370+	0.073	0.489*	0.271	-0.856
Southwest								
Cu	Lactating	0.287+	0.257	0.090	0.148	-0.023	0.009	-0.468*
	Growing	0.182	0.022	0.222	0.076	0.050	0.352*	-0.171
Se	Lactating	-0.057	-0.230	0.065	-0.106	0.147	-0.057	0.736**
	Growing	0.461**	-0.045	0.135	0.129	0.168	0.122	0.362+
Zn	Lactating	-0.121	-0.075	0.016	0.256	-0.237	0.150	0.084
	Growing	-0.139	-0.335*	0.119	0.039	-0.098	0.104	0.153

[a] Correlation coefficients based on the following number of samples: 12 samples from each farm (6 lactating and 6 growing), with 4, 4 and 6 farms within Northeast, Central and Southwest regions, respectively, for each season (rainy and dry); except for selenium, 8 samples from each farm (4 lactating and 4 growing).

[+] $(P < 0.10)$.

[*] $(P < 0.05)$.

[**] $(P < 0.01)$.

TABLE 47. MACROMINERAL AND CRUDE PROTEIN COMPOSITION OF FORAGE SPECIES COLLECTED IN EACH SEASON

			Percent dry matter											
		No. of	Ca (< 0.3)[a]		K (< 0.8)[a]		Mg (< 0.2)[a]		Na (< 0.06)[a]		P (< 0.25)[a]		C.P. (< 7)[a]	
Species	Season	samples	Mean[b]	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Echinochloa	Rainy	6	0.33	± 0.15	2.9	± 0.9	0.29	± 0.15	0.14	± 0.08	0.22	± 0.05	8.0	± 1.7
polystachia	Dry	2	0.25	± 0.00	2.3	± 0.0	0.30	± 0.00	0.10	± 0.01	0.32	± 0.04	7.8	± 1.0
Cynodon	Rainy	8	0.35	± 0.03	2.3	± 0.7	0.21	± 0.10	0.08	± 0.06	0.27	± 0.09	9.8	± 2.6
dactylon	Dry	2	0.29	± 0.05	1.5	± 0.3	0.12	± 0.01	0.04	± 0.01	0.25	± 0.03	8.2	± 0.7
Andropogon	Rainy	2	0.33	± 0.01	2.2	± 0.1	0.11	± 0.00	0.05	± 0.04	0.26	± 0.01	6.9	± 0.1
spp.	Dry	14	0.26	± 0.03	1.0	± 0.1	0.09	± 0.03	0.02	± 0.01	0.09	± 0.02	3.3	± 0.8
Melinis	Rainy	4	0.47	± 0.06	2.0	± 0.3	0.20	± 0.03	0.06	± 0.01	0.23	± 0.04	9.6	± 0.3
minutiflora	Dry	2	0.22	± 0.01	1.0	± 0.1	0.18	± 0.00	0.01	± 0.00	0.24	± 0.01	6.1	± 0.1
Paspalum	Rainy	4	0.52	± 0.01	1.7	± 0.4	0.36	± 0.16	0.05	± 0.01	0.20	± 0.03	6.1	± 0.3
dilatatum	Dry	4	0.61	± 0.15	2.4	± 0.5	0.36	± 0.10	0.03	± 0.03	0.27	± 0.05	8.1	± 1.9
Brachiaria	Rainy	2	0.34	± 0.08	3.9	± 1.4	0.33	± 0.08	0.18	± 0.04	0.39	± 0.04	11.0	± 0.4
spp.	Dry	2	0.21	± 0.02	1.7	± 0.2	0.23	± 0.03	0.07	± 0.04	0.26	± 0.03	7.6	± 0.3
Cynodon	Rainy	25	0.32	± 0.12	2.2	± 1.0	0.16	± 0.08	0.06	± 0.04	0.27	± 0.15	8.7	± 2.2
plectostachyum	Dry	22	0.25	± 0.04	1.3	± 0.3	0.11	± 0.03	0.04	± 0.03	0.20	± 0.07	5.5	± 1.3
Paspalum	Rainy	4	0.24	± 0.11	2.2	± 1.1	0.28	± 0.12	0.04	± 0.02	0.33	± 0.09	8.8	± 0.7
spp.	Dry	8	0.38	± 0.17	2.3	± 0.4	0.29	± 0.09	0.03	± 0.02	0.32	± 0.03	8.2	± 1.7
Panicum	Rainy	4	0.32	± 0.13	2.1	± 0.8	0.14	± 0.04	0.03	± 0.01	0.24	± 0.01	7.7	± 1.7
maximum	Dry	2	0.33	± 0.00	0.9	± 0.1	0.23	± 0.00	0.04	± 0.00	0.18	± 0.02	3.8	± 0.1
Chloris	Rainy	0												
gayana	Dry	2	0.47	± 0.09	3.5	± 0.6	0.24	± 0.04	0.04	± 0.02	0.47	± 0.09	9.2	± 0.1

TABLE 47 - continued.

			Percent dry matter											
		No. of	Ca (< 0.3)[a]		K (< 0.8)[a]		Mg (< 0.2)[a]		Na (< 0.06)[a]		P (< 0.25)[a]		C.P. (< 7)[a]	
Species	Season	samples	Mean[b]	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Hyparrhenia	Rainy	6	0.31	± 0.07	1.1	± 0.6	0.27	± 0.09	0.06	± 0.05	0.14	± 0.03	6.2	± 0.7
rufa	Dry	8	0.28	± 0.04	0.5	± 0.1	0.18	± 0.03	0.02	± 0.01	0.13	± 0.04	4.1	± 1.6
Pennisetum	Rainy	6	0.50	± 0.03	2.6	± 0.7	0.29	± 0.13	0.09	± 0.03	0.40	± 0.02	15.7	± 1.4
clandestinum	Dry	12	0.23	± 0.03	1.5	± 0.3	0.18	± 0.02	0.03	± 0.02	0.31	± 0.05	8.8	± 0.9
Zea	Rainy	2	0.46	± 0.07	3.9	± 0.2	0.20	± 0.02	0.12	± 0.01	0.21	± 0.01	10.3	± 0.1
mays	Dry	0												
Pennisetum	Rainy	1	0.30	± 0.00	2.5	± 0.0	0.12	± 0.00	0.05	± 0.00	0.35	± 0.00	7.1	± 0.0
purpureum	Dry	0												
Digitaria	Rainy	10	0.22	± 0.09	1.5	± 0.9	0.11	± 0.05	0.22	± 0.06	0.23	± 0.10	6.9	± 1.9
decumbens	Dry	4	0.24	± 0.06	0.9	± 0.6	0.09	± 0.04	0.06	± 0.03	0.20	± 0.10	5.2	± 1.0

[a] Critical concentrations (%) according to McDowell et al. (1983).

[b] Mean ± standard deviation.

TABLE 48. MICROMINERAL COMPOSITION OF FORAGE SPECIES COLLECTED IN EACH SEASON

Species	Season	No. of samples	ppm, dry matter basis						
			Fe (< 30)[a]	Co (< 0.1)[a]	Cu (< 10)[a]	Mn (< 40)[a]	Mo (> 6)[a]	Se (< 0.1)[a]	Zn (< 30)[a]
			Mean[b] ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
Echinochloa polystachia	Rainy	6	533 ± 439	0.38 ± 0.14	7 ± 3	175 ± 117	2.54 ± 1.85	0.15 ± 0.03	31 ± 13
	Dry	2	1234 ± 121	0.85 ± 0.07	5 ± 1	412 ± 10	2.94 ± 0.83	0.93 ± 0.01	32 ± 3
Cynodon dactylon	Rainy	8	633 ± 234	0.47 ± 0.21	12 ± 11	73 ± 33	1.15 ± 0.60	0.25 ± 0.21	36 ± 8
	Dry	2	516 ± 151	0.29 ± 0.03	4 ± 5	52 ± 15	0.71 ± 0.34	0.24 ± 0.12	24 ± 8
Andropogon spp.	Rainy	2	174 ± 1	0.16 ± 0.05	5 ± 1	37 ± 1	0.42 ± 0.01	0.03 ± 0.01	22 ± 4
	Dry	14	480 ± 209	0.35 ± 0.25	2 ± 1	71 ± 56	0.19 ± 0.04	0.05 ± 0.02	24 ± 14
Melinis minutiflora	Rainy	4	673 ± 622	0.41 ± 0.02	19 ± 1	148 ± 116	0.47 ± 0.06	0.05 ± 0.04	40 ± 12
	Dry	2	470 ± 5	0.39 ± 0.01	3 ± 1	31 ± 3	0.31 ± 0.01	1.07 ± 0.02	39 ± 4
Paspalum dilatatum	Rainy	4	165 ± 32	0.35 ± 0.04	7 ± 6	100 ± 22	2.34 ± 0.48	0.31 ± 0.02	35 ± 7
	Dry	4	452 ± 341	0.30 ± 0.11	5 ± 2	126 ± 90	0.55 ± 0.19	0.53 ± 0.48	38 ± 4
Brachiaria spp.	Rainy	2	311 ± 62	0.38 ± 0.10	23 ± 7	190 ± 51	0.53 ± 0.08	0.18 ± 0.01	64 ± 25
	Dry	2	1765 ± 6	0.92 ± 0.01	6 ± 1	347 ± 28	1.78 ± 0.10	0.94 ± 0.06	49 ± 11
Cynodon plectostachyum	Rainy	25	308 ± 212	0.38 ± 0.20	10 ± 7	85 ± 30	0.61 ± 0.50	0.10 ± 0.10	31 ± 17
	Dry	22	756 ± 482	0.32 ± 0.16	3 ± 1	81 ± 52	0.39 ± 0.33	0.22 ± 0.38	28 ± 8
Paspalum spp.	Rainy	4	605 ± 106	0.47 ± 0.12	4 ± 1	76 ± 19	2.73 ± 2.06	0.48 ± 0.56	34 ± 16
	Dry	8	617 ± 405	0.45 ± 0.33	5 ± 3	91 ± 53	1.36 ± 0.86	0.75 ± 0.40	35 ± 6
Panicum maximum	Rainy	4	62 ± 16	0.12 ± 0.05	18 ± 19	23 ± 10	0.96 ± 0.70	0.07 ± 0.05	16 ± 1
	Dry	2	321 ± 26	0.22 ± 0.01	2 ± 1	46 ± 3	0.35 ± 0.02	0.06 ± 0.01	26 ± 3
Chloris gayana	Rainy	0							
	Dry	2	375 ± 78	0.17 ± 0.02	5 ± 1	39 ± 9	1.61 ± 0.04	0.92 ± 0.01	32 ± 12

TABLE 48 - continued.

			ppm, dry matter basis						
		No. of	Fe (< 30)[a]	Co (< 0.1)[a]	Cu (< 10)[a]	Mn (< 40)[a]	Mo (> 6)[a]	Se (< 0.1)[a]	Zn (< 30)[a]
Species	Season	samples	Mean[b] S.D.	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.
Hyparrhenia	Rainy	6	135 ± 89	0.15 ± 0.08	2 ± 1	86 ± 97	0.51 ± 0.33	0.12 ± 0.05	19 ± 11
rufa	Dry	8	578 ± 246	0.39 ± 0.06	4 ± 2	71 ± 34	0.27 ± 0.09	0.05 ± 0.04	28 ± 5
Pennisetum	Rainy	6	626 ± 598	0.60 ± 0.04	55 ± 61	78 ± 64	0.29 ± 0.02	0.09 ± 0.01	40 ± 20
clandestinum	Dry	12	550 ± 346	0.39 ± 0.11	37 ± 53	77 ± 54	0.28 ± 0.05	0.81 ± 0.34	56 ± 26
Zea	Rainy	2	774 ± 132	0.40 ± 0.08	160 ± 1	107 ± 12	0.16 ± 0.04	0.02 ± 0.00	28 ± 2
mays	Dry	0							
Pennisetum	Rainy	1	36 ± 0	0.07 ± 0	8 ± 0	14 ± 0	0.43 ± 0	0.06 ± 0	20 ± 0
purpureum	Dry	0							
Digitaria	Rainy	10	253 ± 216	0.27 ± 0.10	45 ± 66	92 ± 53	0.55 ± 0.42	0.09 ± 0.08	30 ± 11
decumbens	Dry	4	1157 ± 528	0.58 ± 0.18	4 ± 1	154 ± 84	0.38 ± 0.25	0.08 ± 0.06	31 ± 6

[a] Critical concentrations (%) according to McDowell et al. (1983).

[b] Mean ± standard deviation.

TABLE 49. FORAGE SPECIES MINERAL AND CRUDE PROTEIN PERCENTAGE MEAN VALUES BELOW CRITICAL LEVEL AS RELATED TO SEASON

Parameter	Critical level[a]	Season	No. of species	% mean values below critical level	Range (maximum - minimum)
Calcium, %	< 0.3	Rainy	14	14	0.52 - 0.22
		Dry	13	69	0.61 - 0.21
Potassium, %	< 0.8	Rainy	14	0	3.9 - 1.1
		Dry	13	8	3.5 - 0.5
Magnesium, %	< 0.2	Rainy	14	36	0.36 - 0.11
		Dry	13	50	0.36 - 0.09
Sodium, %	< 0.06	Rainy	14	36	0.22 - 0.03
		Dry	13	77	0.10 - 0.01
Phosphorus, %	< 0.25	Rainy	14	50	0.40 - 0.14
		Dry	13	54	0.47 - 0.09
Iron, ppm	< 30	Rainy	14	0	774 - 36
		Dry	13	0	1234 - 321
Cobalt, ppm	< 0.1	Rainy	14	7	0.60 - 0.07
		Dry	13	0	0.92 - 0.17
Copper, ppm	< 10	Rainy	14	43	160 - 2
		Dry	13	92	37 - 2
Manganese, ppm	< 40	Rainy	14	21	190 - 14
		Dry	13	15	412 - 31
Molybdenum, ppm	> 6	Rainy	14	0	2.73 - 0.16
		Dry	13	0	2.94 - 0.19
Selenium, ppm	< 0.1	Rainy	14	50	0.48 - 0.03
		Dry	13	31	1.07 - 0.05
Zinc, ppm	< 30	Rainy	14	21	64 - 16
		Dry	13	38	56 - 24
Crude protein, %	7	Rainy	14	29	15.7 - 6.1
		Dry	13	46	9.2 - 3.3

[a] McDowell et al. (1983).

APPENDIX C: DATA

SOIL DATA CODES

Sample (1 to 84)

Type 1 = Soil

Season 1 = Rainy (1980)
2 = Dry (1982)

Region 1 = Northeast
2 = Central
3 = Southwest

Farm 1 = Las Vegas
2 = Onandaga
3 = Panchoy
4 = Sebol
5 = Agua Tibia
6 = Concepción AT
7 = El Rosario
8 = Las Victorias
9 = San Caralampio
10 = El Danubio
11 = San Juan Zapote
12 = Magdalena
13 = Palmira
14 = Verapaz

SOIL DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	MATTER	PH	SALT	AL	CA	K	P	FE	CU	MN	ZN	MG	NA
1	1	1	1	1	1	7.1	5.0	1911	420	2200	296	28.6	13.2	0.4	10.0	25.2	324	32
2	2	1	1	1	1	3.1	5.1	906	260	784	60	14.0	20.4	0.3	5.6	2.2	168	16
3	3	1	1	1	1	7.5	6.5	446	420	2000	256	9.0	196.0	0.8	96.0	16.0	284	32
4	4	1	1	1	2	6.0	6.0	221	198	1800	160	10.1	130.0	2.8	44.0	3.8	281	60
5	5	1	1	1	2	2.2	6.4	238	221	1729	110	5.8	140.0	2.9	20.0	2.9	290	40
6	6	1	1	1	2	3.6	6.1	209	219	1969	121	12.0	122.0	2.4	61.0	3.9	340	39
7	7	1	1	1	3	6.5	6.8	699	192	3480	400	2.6	88.0	2.9	129.0	4.4	512	36
8	8	1	1	1	3	3.3	7.4	446	172	3440	300	56.6	15.6	6.4	19.2	3.3	412	64
9	9	1	1	1	3	2.6	7.3	450	176	3360	308	61.0	14.8	4.0	20.0	3.0	396	80
10	10	1	1	1	4	4.8	6.0	209	200	1000	176	5.2	132.0	3.5	44.0	3.3	376	60
11	11	1	1	1	4	1.3	5.7	228	212	900	44	2.0	31.6	1.6	16.8	1.1	508	36
12	12	1	1	1	4	1.8	6.1	95	200	1000	64	2.4	184.0	3.4	128.0	1.1	388	40
13	13	1	1	2	5	3.2	5.6	293	336	1040	252	2.0	40.0	2.8	520.0	4.8	200	20
14	14	1	1	2	5	3.2	4.5	1143	360	980	224	2.2	30.4	2.3	56.0	4.0	184	24
15	15	1	1	2	5	2.3	5.7	249	480	1180	240	1.6	80.0	2.9	480.0	11.2	180	20
16	16	1	1	2	6	3.2	5.4	291	320	1100	260	1.9	40.0	2.1	58.0	4.5	190	21
17	17	1	1	2	6	3.4	4.6	983	343	984	241	2.1	35.2	2.1	160.1	4.0	198	22
18	18	1	1	2	6	2.9	5.8	269	410	1060	225	2.0	62.0	2.3	380.2	10.3	184	20
19	19	1	1	2	7	4.8	5.8	153	249	1100	188	0.8	16.4	2.5	29.2	1.8	312	29
20	20	1	1	2	7	9.1	5.9	388	780	1240	152	0.2	12.0	0.2	2.2	0.4	296	36
21	21	1	1	2	7	12.9	6.0	480	476	3040	64	0.2	8.0	0.1	1.6	1.0	292	40
22	22	1	1	2	8	5.5	7.5	1303	116	4120	1240	1.4	12.0	0.2	3.5	2.0	596	56
23	23	1	1	2	8	5.0	7.4	1017	252	3200	1880	3.6	14.8	0.5	152.0	10.1	800	76
24	24	1	1	2	8	5.2	7.1	2639	192	4040	1640	6.8	2.4	0.2	10.0	5.6	748	68
25	25	1	1	3	9	6.7	5.6	1432	232	2440	96	2.6	9.2	0.6	11.2	4.8	580	60
26	26	1	1	3	9	5.7	5.5	1771	256	2400	132	3.0	15.2	0.6	17.2	6.0	596	56
27	27	1	1	3	9	3.9	5.7	1005	240	2440	76	2.0	8.0	0.5	12.0	4.4	552	48
28	28	1	1	3	10	4.1	5.7	628	348	1600	204	1.4	8.0	1.0	11.6	3.6	440	40
29	29	1	1	3	10	2.0	5.9	404	420	1560	112	10.9	35.2	4.0	8.0	1.1	276	32
30	30	1	1	3	10	2.1	6.0	413	424	1540	116	11.8	35.2	4.4	7.6	1.2	272	36
31	31	1	1	3	11	5.0	5.5	1562	272	2400	252	4.6	4.8	1.2	26.4	14.4	456	48
32	32	1	1	3	11	3.9	6.3	480	260	2520	268	4.6	4.8	1.2	10.8	11.6	452	36
33	33	1	1	3	11	3.8	5.9	997	284	2520	284	5.0	5.6	1.4	10.8	11.6	444	28
34	34	1	1	3	12	5.1	5.7	1037	284	2480	220	2.8	5.6	0.6	19.2	7.6	512	48
35	35	1	1	3	12	4.5	6.1	864	292	2960	508	7.0	2.8	0.4	11.2	10.8	360	32
36	36	1	1	3	12	4.5	6.0	693	276	2560	216	2.0	2.8	0.5	11.2	6.8	504	44
37	37	1	1	3	13	2.9	5.1	970	448	800	164	63.0	56.0	2.6	13.6	1.8	100	40
38	38	1	1	3	13	4.1	5.0	1401	444	1060	52	36.8	48.0	2.7	23.2	3.0	176	52
39	39	1	1	3	13	3.3	5.8	781	356	2120	360	22.0	12.0	0.9	15.2	7.6	272	40
40	40	1	1	3	14	4.1	6.7	360	216	3600	284	63.6	2.4	11.4	5.2	3.8	684	56
41	41	1	1	3	14	2.0	7.0	258	312	2480	620	48.0	6.4	20.8	8.4	2.0	536	36
42	42	1	1	3	14	1.9	6.4	682	296	2520	600	49.0	6.8	20.8	7.2	1.8	528	36
43	43	1	2	1	1	6.0	6.2	470	148	2120	236	6.9	208.0	2.5	100.0	8.4	368	29
44	44	1	2	1	1	6.6	5.5	254	308	640	60	0.9	136.0	1.9	56.0	3.7	248	36
45	45	1	2	1	1	4.0	5.5	180	152	760	48	10.0	180.0	2.2	44.0	4.8	280	16
46	46	1	2	1	2	11.3	4.6	244	264	1300	148	10.3	124.0	2.0	52.0	12.4	332	40
47	47	1	2	1	2	2.1	5.0	150	320	620	80	3.1	600.0	7.6	68.0	2.8	152	28
48	48	1	2	1	2	7.3	6.5	294	180	2800	416	22.3	25.6	3.7	25.2	4.4	452	28
49	49	1	2	1	3	0.9	6.5	118	176	2280	48	37.2	19.2	6.4	19.2	2.3	512	52
50	50	1	2	1	3	7.6	6.2	447	164	2560	388	3.3	96.0	2.2	76.0	7.2	540	28
51	51	1	2	1	3	5.6	5.5	228	316	1000	136	0.8	340.0	3.8	30.4	3.2	300	56
52	52	1	2	1	4	2.9	5.9	351	192	1000	228	2.8	64.0	1.9	56.0	1.9	360	24
53	53	1	2	1	4	1.7	5.4	91	276	588	20	2.9	108.0	3.1	18.0	1.9	320	52
54	54	1	2	1	4	3.3	6.1	126	164	2480	100	22.0	17.6	2.5	21.2	2.8	500	36
55	55	1	2	2	5	7.8	5.7	348	284	1320	384	1.8	34.8	1.9	42.4	8.0	424	16
56	56	1	2	2	5	8.6	5.7	326	272	1280	524	1.5	52.0	1.8	224.0	9.2	456	12
57	57	1	2	2	5	11.4	5.9	783	292	1300	1120	1.6	56.0	1.0	360.0	11.2	440	52
58	58	1	2	2	6	7.6	5.8	360	283	1215	520	1.7	46.0	1.7	228.0	8.0	420	18
59	59	1	2	2	6	8.3	5.7	325	281	1290	541	1.8	49.0	1.8	204.0	9.6	439	20
60	60	1	2	2	6	11.6	5.9	521	291	1305	590	1.5	53.0	1.8	49.0	10.5	458	36
61	61	1	2	2	7	19.1	5.9	84	792	1520	32	0.2	1.2	0.1	5.6	0.6	120	8
62	62	1	2	2	7	24.0	6.0	252	960	2080	100	0.2	1.6	0.1	10.4	2.2	308	16
63	63	1	2	2	7	19.0	6.0	108	940	1076	44	0.2	0.4	0.1	2.2	0.7	112	12
64	64	1	2	2	8	20.0	5.9	190	392	1600	752	1.0	8.0	1.2	16.0	3.4	500	16

SOIL DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	MATTER	PH	SALT	AL	CA	K	P	FE	CU	MN	ZN	MG	NA
65	65	1	2	2	8	11.8	6.2	131	540	2720	280	0.3	0.4	0.2	2.2	1.6	240	20
66	66	1	2	2	8	9.3	6.2	143	368	1520	672	1.7	10.4	1.4	32.4	3.4	540	8
67	67	1	2	3	9	6.2	6.4	113	260	1904	260	1.8	9.8	0.4	19.4	4.0	496	16
68	68	1	2	3	9	10.6	6.3	304	312	2360	296	1.7	11.6	0.3	49.0	12.0	640	24
69	69	1	2	3	9	6.2	6.3	309	268	2280	360	1.7	4.8	0.3	19.0	8.4	608	16
70	70	1	2	3	10	6.9	6.3	318	249	1760	720	9.2	35.2	1.9	36.8	6.0	560	32
71	71	1	2	3	10	4.8	6.1	96	392	1400	140	2.1	9.6	0.9	48.0	4.4	396	16
72	72	1	2	3	10	5.2	6.4	159	316	1100	180	3.3	28.4	1.3	34.0	3.9	432	24
73	73	1	2	3	11	3.3	6.6	138	284	2240	284	5.8	2.4	0.8	15.6	9.2	336	20
74	74	1	2	3	11	2.1	6.6	136	308	2000	268	1.2	4.4	1.5	14.0	9.2	360	24
75	75	1	2	3	11	4.0	6.9	197	276	2240	508	1.5	2.8	0.9	11.2	8.4	360	16
76	76	1	2	3	12	6.0	6.6	195	284	2320	400	2.7	2.8	0.6	34.0	9.6	375	12
77	77	1	2	3	12	5.3	6.6	143	268	2280	224	2.8	4.0	0.8	17.2	12.0	368	24
78	78	1	2	3	12	5.8	6.5	86	212	2760	64	0.7	1.2	0.2	9.6	2.3	504	40
79	79	1	2	3	13	6.0	6.1	188	156	1200	180	3.8	39.2	2.2	27.2	3.1	320	28
80	80	1	2	3	13	4.5	5.8	124	400	1000	96	22.0	32.8	2.6	72.0	4.4	212	20
81	81	1	2	3	13	3.3	6.6	272	228	1280	612	14.0	16.4	1.6	32.8	3.0	340	44
82	82	1	2	3	14	9.6	6.0	312	592	1680	244	23.8	44.0	1.8	10.0	7.6	400	60
83	83	1	2	3	14	10.5	5.7	533	600	1680	232	24.7	44.0	1.8	10.0	7.2	389	60
84	84	1	2	3	14	6.0	6.1	353	568	1628	224	14.4	92.0	2.6	34.0	8.0	380	56

FORAGE DATA CODES

Sample (1 to 168)

Type 2 = Forage

Season 1 = Rainy (1980)
2 = Dry (1982)

Region 1 = Northeast
2 = Central
3 = Southwest

Farm 1 = Las Vegas
2 = Onandaga
3 = Panchoy
4 = Sebol
5 = Agua Tibia
6 = Concepción AT
7 = El Rosario
8 = Las Victorias
9 = San Caralampio
10 = El Danubio
11 = San Juan Zapote
12 = Magdalena
13 = Palmira
14 = Verapaz

Species 1 = Echinochloa polystachia
2 = Cynodon dactylon
3 = Andropogon spp.
4 = Melinis minutiflora
5 = Paspalum dilatatum
6 = Brachiaria spp.
7 = Cynodon plectostachyum
8 = Paspalum spp.
9 = Panicum maximum
10 = Chloris gayana
11 = Hyparrhenia rufa
12 = Pennisetum clandestinum
13 = Zea mays
14 = Pennisetum purpureum
15 = Digitaria decumbens

FORAGE DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	SPECIES	CA	K	MG	NA	P	FE	CU	MN	MO	SE	ZN	PROTEIN
1	1	2	1	1	1	1	0.56	2.64	0.49	0.22	0.16	254	8.9	313.2	1.18	0.18	48.2	9.9
2	2	2	1	1	1	1	0.17	1.37	0.45	0.03	0.15	148	7.9	155.5	0.40	0.17	26.0	9.5
3	3	2	1	1	1	11	0.32	2.22	0.40	0.17	0.16	205	4.4	265.5	1.17	0.15	39.4	6.4
4	4	2	1	1	1	11	0.14	1.09	0.39	0.05	0.14	121	3.1	129.3	0.37	0.16	22.0	5.9
5	5	2	1	1	1	7	0.32	4.33	0.37	0.08	0.38	313	15.4	261.9	0.73	0.16	70.6	11.2
6	6	2	1	1	1	7	0.32	4.11	0.37	0.07	0.29	376	14.9	274.6	0.68	0.18	74.8	9.9
7	7	2	1	1	2	5	0.33	1.44	0.52	0.05	0.20	180	14.4	98.2	1.85	0.34	35.7	5.7
8	8	2	1	1	2	5	0.36	1.34	0.46	0.04	0.24	119	7.4	70.1	2.01	0.29	33.8	6.5
9	9	2	1	1	2	2	0.40	3.20	0.29	0.05	0.30	754	8.9	78.4	1.60	0.36	32.9	9.2
10	10	2	1	1	2	2	0.43	3.40	0.31	0.06	0.31	780	13.5	88.6	1.71	0.37	38.3	9.3
11	11	2	1	1	2	2	0.45	2.15	0.33	0.07	0.20	760	10.4	70.2	1.61	0.60	32.1	9.2
12	12	2	1	1	2	2	0.41	2.20	0.27	0.04	0.19	730	9.4	76.1	1.69	0.39	36.2	8.9
13	13	2	1	1	3	5	0.31	1.95	0.22	0.05	0.19	190	3.0	112.6	2.65	0.32	26.5	5.9
14	14	2	1	1	3	5	0.40	2.15	0.23	0.04	0.18	170	2.3	119.7	2.84	0.29	42.5	6.1
15	15	2	1	1	3	8	0.42	3.08	0.38	0.05	0.43	507	4.5	86.7	3.60	1.23	48.4	9.1
16	16	2	1	1	3	8	0.40	3.09	0.38	0.06	0.36	557	3.8	93.1	5.22	0.60	44.4	9.6
17	17	2	1	1	3	9	0.09	2.66	0.15	0.07	0.25	66	5.2	20.9	1.73	0.11	15.4	6.3
18	18	2	1	1	3	9	0.09	2.63	0.16	0.01	0.23	58	5.7	25.8	1.38	0.10	14.3	6.2
19	19	2	1	1	4	7	0.45	3.49	0.32	0.06	0.83	605	5.0	222.0	1.73	0.76	31.2	12.6
20	20	2	1	1	4	7	0.42	4.01	0.19	0.12	0.46	209	11.8	288.6	2.36	0.43	24.1	10.3
21	21	2	1	1	4	1	0.42	3.43	0.27	0.09	0.28	546	4.7	205.1	1.31	0.16	29.9	6.2
22	22	2	1	1	4	1	0.44	3.80	0.18	0.09	0.20	199	11.5	291.9	3.13	0.17	24.5	5.9
23	23	2	1	1	4	6	0.31	2.98	0.27	0.20	0.41	267	18.3	154.4	0.47	0.17	46.9	11.3
24	24	2	1	1	4	6	0.45	4.97	0.39	0.15	0.36	355	28.0	226.2	0.59	0.18	81.9	10.8
25	25	2	1	2	5	4	0.40	2.04	0.24	0.05	0.27	1269	19.9	261.9	0.54	0.03	55.4	9.6
26	26	2	1	2	5	4	0.39	1.62	0.19	0.05	0.20	1150	16.7	233.5	0.40	0.02	41.4	10.0
27	27	2	1	2	5	13	0.34	3.77	0.18	0.11	0.21	680	160.7	98.4	0.13	0.02	26.1	10.4
28	28	2	1	2	5	13	0.45	4.09	0.21	0.13	0.20	867	159.3	115.1	0.19	0.02	29.2	10.2
29	29	2	1	2	5	12	0.55	3.50	0.46	0.12	0.43	1377	160.7	154.3	0.29	0.10	49.7	16.6
30	30	2	1	2	5	12	0.67	3.60	0.47	0.13	0.38	1399	100.2	163.9	0.26	0.09	77.6	17.3
31	31	2	1	2	6	4	0.43	2.15	0.18	0.06	0.25	103	19.2	35.2	0.50	0.10	30.2	9.6
32	32	2	1	2	6	4	0.40	2.19	0.20	0.07	0.20	170	18.2	60.4	0.43	0.08	31.2	9.3
33	33	2	1	2	6	12	0.57	1.98	0.19	0.09	0.40	157	16.2	50.3	0.31	0.08	28.3	13.4
34	34	2	1	2	6	12	0.59	2.30	0.20	0.09	0.41	153	15.3	25.2	0.29	0.09	34.2	14.5
35	35	2	1	2	6	12	0.61	2.09	0.21	0.05	0.41	421	19.5	31.8	0.30	0.08	26.4	16.3
36	36	2	1	2	6	12	0.58	2.10	0.23	0.06	0.38	250	18.6	40.2	0.31	0.09	25.4	15.9
37	37	2	1	2	7	11	0.11	0.67	0.18	0.02	0.11	103	1.2	14.2	0.34	0.04	14.4	5.5
38	38	2	1	2	7	11	0.11	0.68	0.18	0.02	0.10	101	1.0	11.4	0.34	0.06	12.5	5.4
39	39	2	1	2	7	7	0.25	2.35	0.15	0.07	0.26	191	2.8	22.2	0.35	0.06	19.3	9.7
40	40	2	1	2	7	7	0.25	2.17	0.14	0.04	0.24	172	2.8	17.8	0.70	0.08	18.9	8.9
41	41	2	1	2	7	1	0.42	3.25	0.17	0.22	0.27	1177	5.9	52.2	4.98	0.12	42.9	8.5
42	42	2	1	2	7	1	0.28	3.16	0.16	0.20	0.23	996	3.8	34.2	4.24	0.10	14.4	8.1
43	43	2	1	2	8	7	0.21	2.34	0.20	0.03	0.24	250	5.2	46.3	0.90	0.08	49.5	10.1
44	44	2	1	2	8	7	0.21	2.27	0.21	0.04	0.23	244	6.6	45.2	0.86	0.10	45.1	9.6
45	45	2	1	2	8	7	0.26	2.36	0.17	0.02	0.18	391	7.4	34.4	0.47	0.10	51.1	10.0
46	46	2	1	2	8	7	0.27	2.39	0.17	0.03	0.19	407	6.9	36.2	0.52	0.09	56.8	9.9
47	47	2	1	2	8	11	0.12	0.97	0.26	0.02	0.14	149	1.0	46.0	0.46	0.17	13.7	7.0
48	48	2	1	2	8	11	0.13	0.89	0.23	0.02	0.16	132	1.1	49.2	0.38	0.13	10.7	6.8
49	49	2	1	3	9	7	0.52	1.68	0.12	0.08	0.20	296	32.8	58.5	0.37	0.01	18.8	6.7
50	50	2	1	3	9	7	0.44	1.64	0.14	0.07	0.19	321	38.8	71.1	0.35	0.05	21.1	6.9
51	51	2	1	3	9	7	0.52	1.71	0.14	0.05	0.14	272	26.0	60.2	0.19	0.03	25.7	5.1
52	52	2	1	3	9	7	0.44	1.55	0.13	0.04	0.16	289	26.8	65.3	0.16	0.06	25.2	5.8
53	53	2	1	3	9	15	0.22	2.41	0.12	0.30	0.22	150	172.8	110.0	0.19	0.25	29.4	6.4
54	54	2	1	3	9	15	0.25	2.54	0.12	0.30	0.21	139	164.5	109.9	0.19	0.19	30.8	6.2
55	55	2	1	3	10	8	0.65	1.80	0.25	0.02	0.26	604	4.9	72.4	1.43	0.02	29.3	8.1
56	56	2	1	3	10	8	0.41	0.85	0.12	0.01	0.25	752	3.6	50.9	0.68	0.06	14.1	8.4
57	57	2	1	3	10	7	0.15	2.69	0.19	0.05	0.19	138	6.8	17.7	0.61	0.01	26.7	8.7
58	58	2	1	3	10	7	0.35	1.27	0.10	0.02	0.18	150	3.4	68.0	0.37	0.02	16.6	8.3
59	59	2	1	3	10	15	0.46	2.28	0.17	0.19	0.23	825	34.7	128.1	1.11	0.02	51.5	8.8
60	60	2	1	3	10	15	0.34	1.29	0.08	0.11	0.22	309	20.4	61.0	0.54	0.03	25.2	8.6
61	61	2	1	3	11	9	0.20	2.21	0.16	0.04	0.25	80	47.2	34.1	0.50	0.01	15.7	9.3
62	62	2	1	3	11	9	0.10	0.91	0.07	0.01	0.24	42	14.9	9.3	0.26	0.04	16.6	9.1
63	63	2	1	3	11	15	0.15	1.03	0.06	0.15	0.29	93	13.5	19.2	0.22	0.12	22.4	6.6
64	64	2	1	3	11	15	0.11	1.06	0.06	0.19	0.26	73	13.9	21.1	0.22	0.13	20.5	6.5
65	65	2	1	3	11	7	0.20	1.14	0.06	0.02	0.34	99	3.8	11.7	0.16	0.02	15.0	6.8
66	66	2	1	3	11	7	0.21	1.09	0.06	0.03	0.33	94	3.6	12.5	0.15	0.03	17.9	7.2
67	67	2	1	3	12	3	0.19	2.18	0.11	0.02	0.27	174	5.1	36.6	0.43	0.03	24.8	6.8

FORAGE CATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	SPECIES	CA	K	MG	NA	P	FE	CU	MN	MO	SE	ZN	PROTEIN
68	68	2	1	3	12	3	0.12	2.16	0.11	0.08	0.25	173	4.5	38.3	0.41	0.02	19.7	7.0
69	69	2	1	3	12	7	0.25	2.62	0.12	0.05	0.29	108	5.8	25.3	0.19	0.01	23.0	13.2
70	70	2	1	3	12	7	0.22	3.13	0.13	0.04	0.27	132	5.5	24.8	0.23	0.01	27.4	10.6
71	71	2	1	3	12	2	0.89	1.40	0.08	0.06	0.18	520	4.9	63.5	0.31	0.10	27.7	7.4
72	72	2	1	3	12	2	0.56	1.43	0.08	0.05	0.20	589	4.6	64.7	0.31	0.09	28.4	7.1
73	73	2	1	3	13	7	0.76	0.92	0.08	0.07	0.14	753	2.8	117.1	0.40	0.01	16.4	5.7
74	74	2	1	3	13	7	0.96	0.79	0.09	0.11	0.15	750	7.4	163.8	0.55	0.04	21.2	5.8
75	75	2	1	3	13	15	0.26	0.66	0.08	0.26	0.13	216	1.7	150.4	0.52	0.03	27.3	4.5
76	76	2	1	3	13	15	0.33	0.67	0.08	0.27	0.14	195	2.2	141.0	0.54	0.03	20.8	4.9
77	77	2	1	3	13	7	0.79	0.96	0.07	0.06	0.14	817	2.2	112.3	0.48	0.03	16.1	5.9
78	78	2	1	3	13	15	0.30	0.57	0.07	0.25	0.16	222	2.7	146.0	0.57	0.02	29.6	5.6
79	79	2	1	3	14	15	0.25	2.84	0.21	0.21	0.47	311	25.1	33.5	1.44	0.04	46.7	10.8
80	80	2	1	3	14	14	0.07	2.46	0.12	0.05	0.35	36	7.6	14.3	0.43	0.06	20.1	7.1
81	81	2	1	3	14	2	0.47	2.48	0.17	0.21	0.41	818	38.5	130.9	1.14	0.02	53.7	14.9
82	82	2	1	3	14	2	0.14	2.02	0.14	0.10	0.40	110	4.7	10.4	0.83	0.06	38.3	12.2
83	83	2	1	3	14	7	0.36	1.93	0.14	0.21	0.38	157	5.5	31.2	0.83	0.02	37.6	9.2
84	84	2	1	3	14	7	0.27	1.86	0.14	0.04	0.39	154	4.6	33.3	0.80	0.04	33.8	9.1
85	85	2	2	1	1	11	0.46	0.49	0.16	0.02	0.14	882	2.7	115.1	0.27	0.11	24.7	6.4
86	86	2	2	1	1	11	0.48	0.56	0.19	0.02	0.13	235	3.3	120.6	0.18	0.12	34.1	6.9
87	87	2	2	1	1	8	0.94	2.27	0.43	0.05	0.35	1140	9.8	167.5	0.62	0.12	39.3	11.6
88	88	2	2	1	1	8	0.96	2.28	0.45	0.04	0.30	1241	9.4	158.2	0.48	0.11	36.0	10.1
89	89	2	2	1	1	5	0.41	2.36	0.49	0.09	0.35	840	8.2	193.5	0.54	0.13	38.4	10.9
90	90	2	2	1	1	5	0.36	1.75	0.39	0.01	0.24	637	5.4	213.6	0.28	0.10	42.7	8.0
91	91	2	2	1	2	1	0.80	2.31	0.30	0.09	0.35	1320	5.4	419.2	2.35	0.92	33.9	8.5
92	92	2	2	1	2	1	0.90	2.31	0.30	0.10	0.29	1148	4.6	405.2	3.53	0.94	29.9	7.1
93	93	2	2	1	2	7	0.69	1.95	0.16	0.09	0.25	1493	3.7	200.0	0.91	1.04	24.7	6.7
94	94	2	2	1	2	7	0.59	2.18	0.17	0.06	0.23	1596	3.3	249.8	1.55	1.01	37.7	6.3
95	95	2	2	1	2	6	0.91	1.85	0.25	0.04	0.28	1761	6.5	367.1	1.85	0.98	56.4	7.8
96	96	2	2	1	2	6	0.93	1.62	0.21	0.09	0.24	1769	6.0	327.4	1.71	0.90	40.7	7.4
97	97	2	2	1	3	8	0.10	2.44	0.20	0.01	0.37	179	1.7	34.5	1.53	0.96	27.5	7.0
98	98	2	2	1	3	8	0.12	2.46	0.21	0.01	0.33	190	1.9	38.5	1.74	1.02	29.6	6.7
99	99	2	2	1	3	5	0.21	2.80	0.28	0.02	0.25	174	3.4	48.9	0.72	1.00	34.9	7.0
100	100	2	2	1	3	5	0.20	2.64	0.27	0.01	0.24	157	3.3	47.3	0.66	0.89	34.7	6.6
101	101	2	2	1	3	8	0.33	2.86	0.23	0.02	0.29	387	3.9	54.4	2.61	1.01	30.0	7.1
102	102	2	2	1	3	8	0.34	2.90	0.27	0.03	0.31	405	3.4	56.1	2.48	1.02	31.7	7.2
103	103	2	2	1	4	7	0.39	1.32	0.13	0.03	0.30	1086	2.7	90.8	0.64	0.97	32.9	8.3
104	104	2	2	1	4	7	0.33	1.36	0.13	0.04	0.28	783	3.3	79.5	0.64	0.99	23.6	8.0
105	105	2	2	1	4	8	0.39	1.88	0.28	0.03	0.30	667	3.6	112.6	0.67	0.91	45.6	8.2
106	106	2	2	1	4	8	0.41	1.68	0.27	0.05	0.31	728	4.7	109.3	0.76	0.82	37.1	8.0
107	107	2	2	1	4	10	0.16	3.11	0.21	0.05	0.53	320	5.0	32.2	1.58	0.92	24.1	9.1
108	108	2	2	1	4	10	0.19	3.98	0.27	0.02	0.40	430	5.3	45.0	1.64	0.91	40.7	9.3
109	109	2	2	2	5	12	0.55	1.71	0.19	0.01	0.26	1025	11.3	187.1	0.32	0.99	98.9	7.2
110	110	2	2	2	5	12	0.52	1.55	0.16	0.01	0.24	882	13.1	172.5	0.26	1.05	74.4	8.1
111	111	2	2	2	5	12	0.25	1.95	0.17	0.02	0.32	380	138.7	76.6	0.23	0.92	90.3	8.8
112	112	2	2	2	5	12	0.27	1.94	0.18	0.01	0.26	396	34.4	89.5	0.23	0.90	90.8	7.9
113	113	2	2	2	5	12	0.31	1.24	0.17	0.02	0.38	443	110.1	79.9	0.29	0.98	51.0	10.0
114	114	2	2	2	5	12	0.31	1.31	0.19	0.01	0.30	466	121.2	92.5	0.22	0.93	48.3	10.3
115	115	2	2	2	6	4	0.38	1.00	0.18	0.01	0.25	467	2.8	29.0	0.30	1.06	35.8	6.2
116	116	2	2	2	6	4	0.39	1.10	0.18	0.01	0.23	474	3.4	33.4	0.32	1.09	41.8	6.0
117	117	2	2	2	6	12	0.33	1.20	0.15	0.05	0.30	310	4.5	24.2	0.24	0.99	33.4	9.4
118	118	2	2	2	6	12	0.36	1.00	0.13	0.05	0.28	263	5.0	20.8	0.27	0.98	48.0	8.5
119	119	2	2	2	6	12	0.38	1.62	0.19	0.04	0.32	179	1.6	44.2	0.28	0.98	47.1	9.7
120	120	2	2	2	6	12	0.35	1.50	0.18	0.05	0.33	170	2.0	33.9	0.26	0.95	43.5	9.0
121	121	2	2	2	7	11	0.33	0.69	0.14	0.03	0.19	585	6.9	76.4	0.27	0.04	28.5	3.7
122	122	2	2	2	7	11	0.32	0.73	0.14	0.02	0.18	621	6.5	86.8	0.24	0.03	32.3	3.8
123	123	2	2	2	7	11	0.38	0.51	0.20	0.01	0.09	817	2.6	48.9	0.45	0.03	28.5	3.2
124	124	2	2	2	7	11	0.37	0.56	0.19	0.01	0.08	795	2.6	56.5	0.36	0.04	27.0	3.3
125	125	2	2	2	7	11	0.39	0.43	0.21	0.01	0.09	351	2.6	32.4	0.21	0.02	27.0	2.7
126	126	2	2	2	7	11	0.39	0.34	0.19	0.01	0.10	338	2.8	33.6	0.21	0.03	19.0	2.9
127	127	2	2	2	8	7	0.21	1.27	0.12	0.01	0.28	234	2.7	95.4	0.18	0.01	32.7	4.0
128	128	2	2	2	8	7	0.19	1.24	0.13	0.02	0.24	222	2.4	97.1	0.18	0.03	23.7	3.9
129	129	2	2	2	8	7	0.21	1.66	0.15	0.02	0.36	231	2.7	76.4	0.21	0.01	28.1	6.7
130	130	2	2	2	8	7	0.20	1.75	0.15	0.01	0.30	223	3.4	78.6	0.21	0.02	38.0	6.9
131	131	2	2	2	8	12	0.55	1.42	0.20	0.03	0.37	1076	3.7	47.6	0.36	0.03	23.6	8.1
132	132	2	2	2	8	12	0.55	1.53	0.20	0.02	0.39	1013	3.0	50.2	0.36	0.03	23.5	8.0
133	133	2	2	3	9	2	0.26	1.05	0.12	0.03	0.20	680	1.7	38.8	0.15	0.07	31.6	7.2
134	134	2	2	3	9	2	0.28	1.11	0.12	0.02	0.22	692	2.1	20.5	0.21	0.06	36.4	7.1
135	135	2	2	3	9	7	0.13	1.20	0.13	0.03	0.16	603	1.5	31.0	0.24	0.05	29.9	5.3

FORAGE DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	SPECIES	CA	K	MG	NA	P	FE	CU	MN	MO	SE	ZN	PROTEIN
136	136	2	2	3	9	7	0.12	1.35	0.13	0.01	0.19	420	2.2	29.9	0.21	0.04	31.2	5.2
137	137	2	2	3	9	7	0.16	1.21	0.08	0.05	0.10	344	1.6	64.5	0.18	0.06	37.8	5.2
138	138	2	2	3	9	7	0.14	1.29	0.09	0.07	0.15	425	2.0	72.9	0.30	0.05	42.0	5.3
139	139	2	2	3	10	15	0.44	1.55	0.14	0.03	0.26	1577	3.0	94.6	0.74	0.11	30.7	6.0
140	140	2	2	3	10	15	0.42	1.33	0.10	0.03	0.30	384	3.2	68.3	0.24	0.14	23.8	6.2
141	141	2	2	3	10	7	0.45	1.39	0.13	0.04	0.11	711	3.4	98.3	0.47	0.07	27.2	5.8
142	142	2	2	3	10	7	0.44	1.38	0.10	0.05	0.12	328	1.9	73.2	0.30	0.05	23.9	5.6
143	143	2	2	3	10	7	0.50	1.24	0.13	0.04	0.16	1253	2.7	94.6	0.18	0.06	40.2	5.6
144	144	2	2	3	10	7	0.47	1.12	0.11	0.04	0.18	1092	2.7	73.2	0.15	0.06	37.7	5.5
145	145	2	2	3	11	3	0.79	0.82	0.08	0.05	0.09	790	4.6	162.6	0.24	0.06	12.5	4.5
146	146	2	2	3	11	3	0.70	0.86	0.08	0.03	0.13	811	4.6	158.2	0.18	0.06	18.0	4.3
147	147	2	2	3	11	9	0.23	0.95	0.23	0.04	0.16	339	1.7	48.3	0.33	0.06	28.1	3.9
148	148	2	2	3	11	9	0.21	0.80	0.23	0.04	0.19	302	2.0	43.8	0.36	0.05	23.2	3.7
149	149	2	2	3	11	7	0.24	1.09	0.07	0.08	0.16	260	1.4	27.3	0.18	0.07	19.2	3.8
150	150	2	2	3	11	7	0.25	0.96	0.07	0.10	0.21	301	2.5	19.6	0.21	0.06	18.7	3.8
151	151	2	2	3	12	3	0.19	1.01	0.13	0.01	0.08	247	1.1	32.2	0.21	0.06	36.8	3.4
152	152	2	2	3	12	3	0.19	1.13	0.14	0.01	0.12	325	1.1	55.2	0.21	0.05	51.7	3.2
153	153	2	2	3	12	3	0.21	0.95	0.08	0.03	0.09	427	1.0	37.2	0.15	0.08	10.8	3.0
154	154	2	2	3	12	3	0.24	0.90	0.08	0.02	0.09	372	1.0	46.5	0.12	0.07	20.1	3.1
155	155	2	2	3	12	3	0.26	0.93	0.06	0.01	0.08	476	1.1	38.2	0.21	0.02	21.4	2.1
156	156	2	2	3	12	3	0.22	0.85	0.05	0.01	0.07	393	0.6	34.4	0.18	0.03	17.6	2.6
157	157	2	2	3	13	15	0.70	0.34	0.06	0.09	0.12	1309	3.6	223.2	0.21	0.03	31.6	4.2
158	158	2	2	3	13	15	0.77	0.37	0.07	0.09	0.10	1358	4.4	228.2	0.33	0.03	37.7	4.5
159	159	2	2	3	13	7	0.30	1.26	0.08	0.01	0.18	1261	2.5	51.5	0.24	0.03	22.6	3.9
160	160	2	2	3	13	7	0.21	1.13	0.08	0.03	0.20	1225	2.0	41.5	0.27	0.03	15.9	3.8
161	161	2	2	3	13	7	0.31	0.91	0.07	0.02	0.12	1238	6.1	63.8	0.59	0.06	14.6	5.1
162	162	2	2	3	13	7	0.42	1.01	0.08	0.04	0.12	1294	6.5	66.5	0.53	0.06	16.7	5.2
163	163	2	2	3	14	2	0.25	1.65	0.12	0.03	0.28	401	2.0	59.7	0.81	0.25	20.6	8.5
164	164	2	2	3	14	2	0.29	1.61	0.11	0.03	0.27	412	2.2	57.9	0.84	0.24	21.1	8.4
165	165	2	2	3	14	2	0.26	1.56	0.12	0.04	0.26	386	1.9	57.6	0.94	0.40	15.6	8.3
166	166	2	2	3	14	2	0.34	1.81	0.13	0.06	0.27	718	14.8	64.9	1.03	0.35	28.6	8.6
167	167	2	2	3	14	2	0.32	1.55	0.13	0.03	0.26	397	2.1	59.7	0.72	0.25	22.1	9.0
168	168	2	2	3	14	2	0.29	1.47	0.10	0.06	0.26	445	1.5	54.0	0.96	0.27	13.1	8.8

ANIMAL TISSUE DATA CODES

Sample Blood plasma (1 to 560)
Bone (1 to 56)
Liver (1 to 560)

Type 3 = Liver
4 = Blood plasma
5 = Bone

Season 1 = Rainy (1980)
2 = Dry (1982)

Region 1 = Northeast
2 = Central
3 = Southwest

Farm 1 = Las Vegas
2 = Onandaga
3 = Panchoy
4 = Sebol
5 = Agua Tibia
6 = Concepción AT
7 = El Rosario
8 = Las Victorias
9 = San Caralampio
10 = El Danubio
11 = San Juan Zapote
12 = Magdalena
13 = Palmira
14 = Verapaz

Class 1 = Pregnant-lactating cow
2 = Growing steer

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                                                  PLASMA DATA
OBS   SAMPLE   TYPE   SEASON   REGION   FARM   CLASS   P_CA   F_MG   P_P   P_CU   P_SE   P_ZN

  1      1       4       1        1       1      1      8.4    2.9   1.6   0.69   0.09   0.96
  2      2       4       1        1       1      1      8.4    3.1   1.7   0.63   0.09   1.03
  3      3       4       1        1       1      1      8.4    3.0   1.6   0.64   0.09   1.09
  4      4       4       1        1       1      1      7.8    2.8   1.5   0.68   0.09   0.97
  5      5       4       1        1       1      1      7.7    2.8   2.4   0.69   0.07   1.38
  6      6       4       1        1       1      1      7.4    2.9   2.6   0.74   0.07   0.75
  7      7       4       1        1       1      1      7.9    3.2   1.4   0.83   0.07   0.84
  8      8       4       1        1       1      1      8.9    2.9   1.9   0.73   0.07   1.05
  9      9       4       1        1       1      1      9.1    3.0   1.5   0.62   0.06   0.84
 10     10       4       1        1       1      1      8.4    2.8   1.9   0.66   0.07   1.16
 11     11       4       1        1       1      2      8.6    2.6   3.7   0.63   0.06   1.14
 12     12       4       1        1       1      2      8.1    2.5   3.6   0.97   0.06   0.66
 13     13       4       1        1       1      2      8.2    2.4   3.0   1.22   0.10   0.78
 14     14       4       1        1       1      2      8.2    2.7   1.7   0.92   0.07   1.07
 15     15       4       1        1       1      2      8.3    2.4   2.6   0.64   0.11   0.81
 16     16       4       1        1       1      2      8.3    2.5   3.3   0.92   0.06   0.75
 17     17       4       1        1       1      2      8.4    2.7   2.3   0.71   0.06   0.79
 18     18       4       1        1       1      2      8.4    2.7   2.4   0.77   0.09   0.95
 19     19       4       1        1       1      2      8.4    2.6   2.3   0.86   0.06   0.85
 20     20       4       1        1       1      2      8.9    2.9   2.3   0.75   0.06   0.84
 21     21       4       1        1       2      1      8.4    2.6   6.5   0.42   0.11   1.36
 22     22       4       1        1       2      1      8.5    2.5   6.1   0.37   0.16   1.26
 23     23       4       1        1       2      1      8.9    2.4   5.1   0.46   0.14   1.27
 24     24       4       1        1       2      1      8.9    2.4   5.8   0.48   0.11   1.30
 25     25       4       1        1       2      1      7.9    2.9   6.8   0.73   0.11   0.70
 26     26       4       1        1       2      1      7.8    2.4   6.1   0.25   0.16   0.95
 27     27       4       1        1       2      1      8.1    2.4   6.5   0.38   0.11   0.93
 28     28       4       1        1       2      1      8.5    2.5   6.4   0.18   0.11   0.94
 29     29       4       1        1       2      1      8.9    2.4   6.1   0.17   0.11   0.94
 30     30       4       1        1       2      1      7.8    2.8   6.3   0.49   0.10   0.62
 31     31       4       1        1       2      2      8.0    2.5   6.2   0.59   0.11   0.86
 32     32       4       1        1       2      2      8.4    2.8   5.3   0.45   0.10   1.02
 33     33       4       1        1       2      2      9.1    2.8   6.8   0.44   0.11   0.79
 34     34       4       1        1       2      2      8.4    2.6   5.8   0.29   0.16   1.10
 35     35       4       1        1       2      2      8.4    2.5   6.4   0.45   0.16   1.08
 36     36       4       1        1       2      2      9.2    2.6   5.9   0.34   0.11   1.39
 37     37       4       1        1       2      2      9.2    2.8   5.1   0.36   0.14   1.33
 38     38       4       1        1       2      2      9.4    2.5   6.3   0.56   0.10   1.23
 39     39       4       1        1       2      2      8.7    2.6   5.8   0.27   0.10   1.54
 40     40       4       1        1       2      2      8.0    3.0   8.2   0.47   0.10   1.60
 41     41       4       1        1       3      1      8.8    2.7   3.3   0.34   0.14   0.96
 42     42       4       1        1       3      1      8.4    2.9   2.8   0.25   0.10   0.89
 43     43       4       1        1       3      1      8.4    2.7   4.0   0.16   0.34   1.04
 44     44       4       1        1       3      1      7.7    3.0   5.1   0.16   0.21   0.96
 45     45       4       1        1       3      1      8.9    3.0   3.8   0.49   0.30   1.15
 46     46       4       1        1       3      1      8.4    2.5   3.0   0.42   0.30   0.93
 47     47       4       1        1       3      1      8.0    2.5   4.2   0.48   0.21   0.79
 48     48       4       1        1       3      1      8.4    2.7   3.6   0.35   0.14   1.04
 49     49       4       1        1       3      1      8.4    3.0   4.4   0.41   0.14   0.91
 50     50       4       1        1       3      1      8.4    3.0   6.3   0.25   0.27   1.21
 51     51       4       1        1       3      2      8.9    2.8   6.2   0.45   0.11   1.26
 52     52       4       1        1       3      2      8.5    2.6   5.1   0.37   0.19   1.06
 53     53       4       1        1       3      2      8.4    2.1   3.3   0.42   0.22   0.92
 54     54       4       1        1       3      2      9.2    2.6   5.1   0.35   0.22   0.99
 55     55       4       1        1       3      2      9.1    2.3   4.1   0.38   0.17   0.91
 56     56       4       1        1       3      2      9.2    2.6   5.4   0.40   0.17   1.20
 57     57       4       1        1       3      2      8.7    2.8   6.2   0.57   0.26   0.99
 58     58       4       1        1       3      2      8.5    2.6   6.3   0.29   0.19   1.00
 59     59       4       1        1       3      2      8.4    2.6   5.8   0.49   0.19   1.06
 60     60       4       1        1       3      2      8.1    2.3   5.3   0.49   0.13   0.92
 61     61       4       1        1       4      1      8.0    2.1   5.1   0.61   0.18   0.80
 62     62       4       1        1       4      1      8.2    2.7   5.3   0.24   0.14   0.78
 63     63       4       1        1       4      1      8.4    2.0   4.9   0.47   0.10   0.86
 64     64       4       1        1       4      1      8.2    2.5   3.7   0.23   0.14   0.76
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PLASMA DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	CLASS	P_CA	P_MG	P_P	P_CU	P_SE	P_ZN
65	65	4	1	1	4	1	8.3	2.5	5.5	0.20	0.18	0.90
66	66	4	1	1	4	1	7.8	2.5	4.3	0.18	0.17	0.98
67	67	4	1	1	4	1	8.5	2.6	5.2	0.19	0.14	0.61
68	68	4	1	1	4	1	9.2	2.7	3.5	0.21	0.24	0.73
69	69	4	1	1	4	1	9.2	2.8	4.9	0.11	0.21	1.06
70	70	4	1	1	4	1	8.4	2.2	3.9	0.14	0.21	0.41
71	71	4	1	1	4	2	8.4	2.3	6.6	0.19	0.21	0.61
72	72	4	1	1	4	2	8.4	2.6	5.7	0.17	0.14	0.74
73	73	4	1	1	4	2	7.9	2.5	7.5	0.15	0.15	0.47
74	74	4	1	1	4	2	8.7	2.6	6.7	0.14	0.11	0.60
75	75	4	1	1	4	2	8.4	2.7	5.4	0.13	0.16	0.42
76	76	4	1	1	4	2	8.4	2.6	6.1	0.38	0.14	0.56
77	77	4	1	1	4	2	8.4	2.6	7.1	0.34	0.14	0.56
78	78	4	1	1	4	2	7.8	2.5	7.5	0.21	0.14	0.50
79	79	4	1	1	4	2	8.4	2.3	6.2	0.20	0.13	0.73
80	80	4	1	1	4	2	8.2	2.4	6.7	0.38	0.15	1.03
81	81	4	1	2	5	1	9.1	2.1	5.3	1.18	0.04	0.76
82	82	4	1	2	5	1	9.2	2.3	6.7	1.10	0.02	1.17
83	83	4	1	2	5	1	8.5	2.6	7.1	0.89	0.08	0.93
84	84	4	1	2	5	1	9.3	2.1	5.7	1.15	0.08	1.27
85	85	4	1	2	5	1	9.1	2.4	7.3	1.00	0.03	1.35
86	86	4	1	2	5	1	8.4	2.6	5.7	1.20	0.06	1.30
87	87	4	1	2	5	1	7.9	2.0	6.0	0.89	0.03	1.23
88	88	4	1	2	5	1	7.9	2.1	6.0	0.84	0.03	1.26
89	89	4	1	2	5	1	9.0	2.3	5.9	1.29	0.06	1.09
90	90	4	1	2	5	1	8.7	2.4	6.3	0.89	0.06	0.93
91	91	4	1	2	5	2	8.5	2.4	7.0	1.05	0.02	1.13
92	92	4	1	2	5	2	8.5	2.4	7.0	1.45	0.02	1.36
93	93	4	1	2	5	2	8.4	1.8	6.1	1.03	0.02	1.25
94	94	4	1	2	5	2	7.9	1.9	6.6	0.99	0.02	1.27
95	95	4	1	2	5	2	9.1	2.7	5.4	0.98	0.02	1.13
96	96	4	1	2	5	2	8.4	2.2	6.6	1.05	0.05	1.30
97	97	4	1	2	5	2	8.0	2.1	6.0	1.18	0.04	1.31
98	98	4	1	2	5	2	8.2	2.8	6.3	0.84	0.04	1.03
99	99	4	1	2	5	2	8.2	2.7	6.7	0.94	0.04	1.06
100	100	4	1	2	5	2	8.5	2.5	6.4	1.18	0.04	1.20
101	101	4	1	2	6	1	8.1	2.3	5.9	1.00	0.03	1.12
102	102	4	1	2	6	1	8.0	2.4	5.8	0.99	0.03	1.08
103	103	4	1	2	6	1	8.4	2.6	6.0	0.98	0.04	0.93
104	104	4	1	2	6	1	8.3	2.0	6.3	1.03	0.06	0.90
105	105	4	1	2	6	1	9.1	2.4	5.7	0.77	0.04	0.89
106	106	4	1	2	6	1	8.5	2.8	5.9	0.82	0.03	1.10
107	107	4	1	2	6	1	8.0	2.7	6.0	0.74	0.06	1.06
108	108	4	1	2	6	1	7.9	2.0	4.9	0.64	0.08	1.02
109	109	4	1	2	6	1	8.2	2.1	4.8	0.60	0.02	1.01
110	110	4	1	2	6	1	8.1	2.3	5.9	0.66	0.03	1.17
111	111	4	1	2	6	2	8.3	2.0	6.1	0.60	0.03	1.20
112	112	4	1	2	6	2	8.0	1.9	6.2	1.03	0.02	1.17
113	113	4	1	2	6	2	8.5	2.4	6.3	1.09	0.03	0.93
114	114	4	1	2	6	2	9.1	2.3	6.4	0.61	0.04	0.94
115	115	4	1	2	6	2	7.9	2.2	6.0	1.07	0.06	1.02
116	116	4	1	2	6	2	7.8	2.1	6.0	0.89	0.04	0.98
117	117	4	1	2	6	2	7.9	2.5	6.1	0.93	0.03	1.03
118	118	4	1	2	6	2	8.0	1.9	6.2	0.97	0.03	1.02
119	119	4	1	2	6	2	8.3	2.0	6.0	0.92	0.03	1.10
120	120	4	1	2	6	2	8.7	2.2	5.7	1.01	0.04	0.87
121	121	4	1	2	7	1	8.4	2.3	2.2	0.87	0.02	0.47
122	122	4	1	2	7	1	8.3	2.6	3.6	0.92	0.02	0.53
123	123	4	1	2	7	1	8.4	2.3	2.8	0.70	0.03	0.71
124	124	4	1	2	7	1	7.9	2.3	4.1	0.80	0.03	0.71
125	125	4	1	2	7	1	7.8	2.6	3.9	0.78	0.02	0.85
126	126	4	1	2	7	1	8.4	2.1	3.3	0.94	0.04	0.68
127	127	4	1	2	7	1	8.9	1.9	3.5	1.03	0.04	0.99

PLASMA DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	CLASS	P_CA	P_MG	P_P	P_CU	P_SE	P_ZN
128	128	4	1	2	7	1	7.8	2.2	3.2	0.78	0.03	0.93
129	129	4	1	2	7	1	9.0	2.0	5.0	0.68	0.02	0.97
130	130	4	1	2	7	1	9.1	2.1	4.4	0.78	0.02	0.82
131	131	4	1	2	7	2	8.8	2.4	5.5	0.68	0.03	1.22
132	132	4	1	2	7	2	8.4	2.0	4.1	0.83	0.03	1.23
133	133	4	1	2	7	2	8.2	2.3	4.1	0.80	0.04	1.16
134	134	4	1	2	7	2	8.4	2.6	4.5	0.67	0.04	1.28
135	135	4	1	2	7	2	8.6	1.9	5.4	0.61	0.03	1.22
136	136	4	1	2	7	2	8.1	2.4	3.4	0.61	0.03	1.17
137	137	4	1	2	7	2	8.4	2.2	3.6	0.61	0.02	1.22
138	138	4	1	2	7	2	9.1	2.4	3.5	0.64	0.02	1.35
139	139	4	1	2	7	2	8.7	2.3	5.8	0.69	0.02	1.26
140	140	4	1	2	7	2	8.2	1.9	5.8	0.62	0.03	1.20
141	141	4	1	2	8	1	9.1	2.7	5.7	0.54	0.04	1.20
142	142	4	1	2	8	1	8.4	2.6	5.9	0.66	0.04	1.26
143	143	4	1	2	8	1	8.4	2.3	5.9	0.57	0.06	1.25
144	144	4	1	2	8	1	7.9	2.3	5.9	0.42	0.06	1.28
145	145	4	1	2	8	1	7.9	2.6	5.8	0.70	0.06	1.26
146	146	4	1	2	8	1	8.3	1.5	5.8	0.72	0.08	1.05
147	147	4	1	2	8	1	9.1	2.1	7.9	0.74	0.06	1.31
148	148	4	1	2	8	1	9.4	2.0	6.4	0.58	0.09	1.15
149	149	4	1	2	8	1	9.3	2.1	7.5	0.67	0.09	1.30
150	150	4	1	2	8	1	9.3	2.2	8.0	0.81	0.14	1.34
151	151	4	1	2	8	2	9.2	2.8	5.1	0.63	0.06	1.22
152	152	4	1	2	8	2	8.4	2.1	5.3	1.26	0.06	1.06
153	153	4	1	2	8	2	8.9	2.3	6.0	0.96	0.06	1.27
154	154	4	1	2	8	2	8.7	2.5	5.7	1.23	0.04	1.21
155	155	4	1	2	8	2	8.7	2.6	5.4	1.14	0.06	1.23
156	156	4	1	2	8	2	8.9	2.2	5.7	1.05	0.06	1.29
157	157	4	1	2	8	2	8.5	2.3	6.0	0.80	0.06	1.25
158	158	4	1	2	8	2	9.1	2.2	5.6	1.16	0.06	1.28
159	159	4	1	2	8	2	9.1	1.4	5.9	1.24	0.04	1.05
160	160	4	1	2	8	2	8.9	1.9	8.5	0.66	0.04	1.31
161	161	4	1	3	9	1	8.2	2.4	4.3	1.05	0.04	0.82
162	162	4	1	3	9	1	8.2	1.7	4.9	0.64	0.02	0.90
163	163	4	1	3	9	1	8.3	2.3	3.7	0.77	0.03	0.88
164	164	4	1	3	9	1	7.9	1.8	4.6	0.91	0.03	1.29
165	165	4	1	3	9	1	9.1	2.0	4.1	0.84	0.04	0.74
166	166	4	1	3	9	1	9.3	2.3	5.4	1.17	0.04	0.84
167	167	4	1	3	9	1	8.3	2.2	4.3	0.75	0.04	0.71
168	168	4	1	3	9	1	8.6	2.1	4.4	0.73	0.04	0.78
169	169	4	1	3	9	1	8.0	2.5	5.1	0.64	0.10	0.90
170	170	4	1	3	9	1	7.5	2.4	4.6	1.16	0.05	0.78
171	171	4	1	3	9	2	8.3	2.2	4.6	0.73	0.04	1.13
172	172	4	1	3	9	2	8.5	1.9	5.4	0.96	0.05	0.98
173	173	4	1	3	9	2	9.9	2.0	4.7	1.00	0.03	0.92
174	174	4	1	3	9	2	8.7	2.1	2.9	0.99	0.05	1.11
175	175	4	1	3	9	2	8.6	1.9	4.3	1.02	0.05	0.97
176	176	4	1	3	9	2	8.5	2.0	4.7	0.95	0.03	0.88
177	177	4	1	3	9	2	8.4	2.0	4.3	1.03	0.03	0.93
178	178	4	1	3	9	2	8.4	1.9	3.7	0.74	0.04	0.79
179	179	4	1	3	9	2	8.4	2.0	3.9	1.49	0.04	0.81
180	180	4	1	3	9	2	7.9	1.8	6.7	1.07	0.04	1.11
181	181	4	1	3	10	1	8.3	2.3	4.1	0.69	0.03	0.68
182	182	4	1	3	10	1	8.3	2.6	5.0	0.61	0.03	0.65
183	183	4	1	3	10	1	8.4	2.5	5.0	0.98	0.01	0.93
184	184	4	1	3	10	1	7.9	2.1	4.1	0.78	0.01	0.84
185	185	4	1	3	10	1	8.5	2.0	5.9	0.85	0.04	0.79
186	186	4	1	3	10	1	8.0	1.9	3.6	0.70	0.06	0.77
187	187	4	1	3	10	1	8.0	2.3	3.6	1.07	0.01	0.87
188	188	4	1	3	10	1	7.9	2.2	3.0	1.00	0.01	1.07
189	189	4	1	3	10	1	9.1	2.1	3.0	0.81	0.03	0.85
190	190	4	1	3	10	1	9.6	2.0	3.6	0.97	0.04	0.71

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                                                   PLASMA DATA

OBS   SAMPLE   TYPE   SEASCN   REGION   FARM   CLASS   P_CA   P_MG   P_P   P_CU   P_SE   P_ZN

191    191      4       1        3       10      2      8.3    2.5   6.7   0.95   0.04   1.01
192    192      4       1        3       10      2      8.4    2.4   6.4   0.95   0.02   0.84
193    193      4       1        3       10      2      7.9    2.8   7.8   1.01   0.03   1.08
194    194      4       1        3       10      2      7.8    2.3   7.4   0.81   0.03   0.88
195    195      4       1        3       10      2      8.3    2.1   8.0   0.66   0.03   0.86
196    196      4       1        3       10      2      8.4    2.4   7.9   0.74   0.03   1.06
197    197      4       1        3       10      2      8.1    2.2   7.0   0.74   0.08   0.97
198    198      4       1        3       10      2      7.9    2.2   8.4   0.93   0.06   1.31
199    199      4       1        3       10      2      9.1    1.9   7.7   0.81   0.03   0.99
200    200      4       1        3       10      2      8.3    2.3   8.5   1.03   0.01   0.85
201    201      4       1        3       11      1      8.4    2.1   7.0   1.15   0.06   0.78
202    202      4       1        3       11      1      8.3    2.3   5.0   1.14   0.03   0.60
203    203      4       1        3       11      1      8.7    1.9   2.9   1.00   0.05   0.70
204    204      4       1        3       11      1      8.7    2.3   4.1   1.10   0.05   0.77
205    205      4       1        3       11      1      8.4    2.2   5.0   1.40   0.04   0.90
206    206      4       1        3       11      1      8.2    2.2   4.1   1.28   0.04   0.76
207    207      4       1        3       11      1      8.9    2.6   3.3   0.93   0.03   0.93
208    208      4       1        3       11      1      8.7    2.3   5.7   0.96   0.04   1.01
209    209      4       1        3       11      1      9.1    2.1   3.4   0.62   0.04   0.80
210    210      4       1        3       11      1      9.1    2.1   2.7   0.67   0.05   0.75
211    211      4       1        3       11      2      8.2    2.3   7.0   0.72   0.03   1.06
212    212      4       1        3       11      2      9.2    2.4   8.1   1.01   0.05   1.05
213    213      4       1        3       11      2      9.2    2.4   7.4   0.69   0.03   0.96
214    214      4       1        3       11      2      9.1    2.5   6.3   0.55   0.09   1.06
215    215      4       1        3       11      2      8.0    2.5   6.4   0.87   0.03   1.01
216    216      4       1        3       11      2      8.4    2.1   5.3   0.81   0.06   0.95
217    217      4       1        3       11      2      8.2    2.3   8.0   1.07   0.06   0.91
218    218      4       1        3       11      2      7.8    2.4   6.3   0.77   0.05   0.84
219    219      4       1        3       11      2      7.7    2.2   7.0   1.12   0.05   0.79
220    220      4       1        3       11      2      8.1    2.0   6.1   0.70   0.09   0.94
221    221      4       1        3       12      1      8.3    2.3   5.1   1.22   0.10   0.86
222    222      4       1        3       12      1      8.4    2.8   3.9   0.93   0.05   0.93

223    223      4       1        3       12      1      8.4    2.3   3.9   0.90   0.08   0.85
224    224      4       1        3       12      1      9.0    2.6   3.9   1.04   0.05   0.99
225    225      4       1        3       12      1      9.1    2.3   4.6   0.65   0.04   0.90
226    226      4       1        3       12      1      9.3    2.4   4.4   0.98   0.04   1.09
227    227      4       1        3       12      1      9.1    2.3   3.7   1.27   0.04   0.77
228    228      4       1        3       12      1      9.0    2.2   4.4   1.33   0.04   0.88
229    229      4       1        3       12      1      8.9    2.3   4.1   1.66   0.06   0.99
230    230      4       1        3       12      1      8.6    2.5   3.3   1.64   0.06   0.86
231    231      4       1        3       12      2      8.4    1.8   4.7   1.11   0.04   0.91
232    232      4       1        3       12      2      8.3    2.0   5.7   0.94   0.10   0.77
233    233      4       1        3       12      2      8.3    1.9   4.3   1.01   0.04   0.75
234    234      4       1        3       12      2      8.4    2.0   5.7   1.15   0.04   0.79
235    235      4       1        3       12      2      8.4    2.2   4.7   1.07   0.06   0.71
236    236      4       1        3       12      2      8.4    2.3   6.1   1.00   0.04   1.02
237    237      4       1        3       12      2      8.6    2.1   5.7   1.40   0.05   1.01
238    238      4       1        3       12      2      8.0    2.0   3.6   1.05   0.04   0.64
239    239      4       1        3       12      2      7.9    2.2   6.6   0.92   0.04   0.67
240    240      4       1        3       12      2      9.3    1.9   4.1   1.10   0.04   0.74
241    241      4       1        3       13      1      9.3    2.4   4.1   0.65   0.04   0.96
242    242      4       1        3       13      1      8.4    2.1   5.7   0.84   0.11   1.11
243    243      4       1        3       13      1      7.9    2.0   4.7   0.56   0.09   0.96
244    244      4       1        3       13      1      8.4    1.9   4.9   0.63   0.04   0.95
245    245      4       1        3       13      1      8.5    2.0   2.9   0.81   0.07   0.93
246    246      4       1        3       13      1      8.4    1.9   4.9   0.95   0.07   0.96
247    247      4       1        3       13      1      8.4    2.0   4.7   0.89   0.04   1.06
248    248      4       1        3       13      1      7.4    2.2   5.1   0.85   0.04   0.90
249    249      4       1        3       13      1      7.9    2.2   6.3   1.01   0.09   1.01
250    250      4       1        3       13      1      9.3    2.2   5.7   0.89   0.04   1.19
251    251      4       1        3       13      2      8.5    2.2   6.3   1.13   0.06   1.06
252    252      4       1        3       13      2      8.6    2.1   4.0   1.06   0.04   1.02
253    253      4       1        3       13      2      8.7    2.2   6.3   0.60   0.04   0.92
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PLASMA DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	CLASS	P_CA	P_MG	P_P	P_CU	P_SE	P_ZN
254	254	4	1	3	13	2	8.4	2.5	6.6	0.74	0.04	1.15
255	255	4	1	3	13	2	8.4	2.6	7.0	1.08	0.04	0.97
256	256	4	1	3	13	2	8.4	1.9	7.0	1.04	0.09	1.08
257	257	4	1	3	13	2	7.8	2.2	6.3	1.07	0.04	1.19
258	258	4	1	3	13	2	8.5	2.2	7.0	0.97	0.04	1.03
259	259	4	1	3	13	2	8.9	2.5	7.2	0.62	0.06	0.80
260	260	4	1	3	13	2	8.5	2.7	6.0	0.60	0.05	1.25
261	261	4	1	3	14	1	8.3	2.8	5.6	1.01	0.06	0.66
262	262	4	1	3	14	1	7.9	2.7	4.4	0.96	0.03	0.66
263	263	4	1	3	14	1	9.8	2.6	3.9	0.99	0.04	0.73
264	264	4	1	3	14	1	7.7	2.2	5.7	1.10	0.04	0.74
265	265	4	1	3	14	1	8.3	2.5	4.4	1.02	0.03	0.73
266	266	4	1	3	14	1	8.9	2.6	4.7	0.96	0.05	0.64
267	267	4	1	3	14	1	8.0	2.2	4.7	1.21	0.03	0.80
268	268	4	1	3	14	1	7.9	2.6	4.6	1.23	0.04	0.71
269	269	4	1	3	14	1	8.3	2.8	4.9	1.34	0.03	0.74
270	270	4	1	3	14	1	8.5	2.6	3.9	0.97	0.04	0.65
271	271	4	1	3	14	2	9.2	2.4	4.0	1.40	0.04	0.91
272	272	4	1	3	14	2	8.2	2.4	4.0	1.47	0.04	0.74
273	273	4	1	3	14	2	7.7	2.3	8.1	1.59	0.09	1.25
274	274	4	1	3	14	2	9.1	2.4	6.6	1.39	0.04	1.19
275	275	4	1	3	14	2	8.4	2.0	6.6	1.23	0.07	1.01
276	276	4	1	3	14	2	7.9	2.8	8.7	1.43	0.04	1.31
277	277	4	1	3	14	2	7.8	2.5	6.9	1.43	0.04	1.30
278	278	4	1	3	14	2	9.1	2.0	5.9	1.40	0.07	0.81
279	279	4	1	3	14	2	8.9	2.5	5.9	1.27	0.04	1.24
280	280	4	1	3	14	2	8.5	2.4	7.3	1.30	0.04	0.78
281	281	4	2	1	1	1	7.9	2.5	5.0	0.13	0.09	0.39
282	282	4	2	1	1	1	8.4	2.4	5.6	0.27	0.21	0.21
283	283	4	2	1	1	1	8.5	2.7	6.6	0.18	0.18	0.46
284	284	4	2	1	1	1	7.5	2.7	3.6	0.22	0.18	0.27
285	285	4	2	1	1	1	9.1	2.2	4.0	0.10	0.08	0.30
286	286	4	2	1	1	1	8.3	2.1	6.6	0.39	0.12	0.79
287	287	4	2	1	1	1	8.2	2.8	5.3	0.26	0.11	0.82
288	288	4	2	1	1	1	7.9	2.5	4.4	0.19	0.12	0.69
289	289	4	2	1	1	1	8.2	2.7	5.1	0.57	0.15	0.84
290	290	4	2	1	1	1	8.3	2.7	5.4	0.18	0.12	0.70
291	291	4	2	1	1	2	8.8	2.6	6.6	0.23	0.12	0.81
292	292	4	2	1	1	2	8.9	2.6	4.7	0.29	0.12	0.72
293	293	4	2	1	1	2	7.9	2.7	5.1	0.20	0.26	0.76
294	294	4	2	1	1	2	7.7	2.7	4.7	0.38	0.14	0.58
295	295	4	2	1	1	2	9.0	2.5	5.1	0.50	0.11	0.69
296	296	4	2	1	1	2	8.8	3.0	7.8	0.29	0.11	0.55
297	297	4	2	1	1	2	8.5	2.4	5.6	0.17	0.15	0.68
298	298	4	2	1	1	2	8.6	2.3	4.2	0.32	0.15	0.75
299	299	4	2	1	1	2	8.6	2.5	4.1	0.15	0.11	0.80
300	300	4	2	1	1	2	8.0	2.5	3.9	0.31	0.07	0.76
301	301	4	2	1	2	1	7.9	2.3	4.5	0.50	0.08	0.64
302	302	4	2	1	2	1	8.2	2.5	4.5	0.42	0.14	0.77
303	3C3	4	2	1	2	1	8.4	2.3	6.0	0.46	0.09	0.78
304	304	4	2	1	2	1	8.3	2.5	5.2	0.39	0.11	1.04
305	305	4	2	1	2	1	8.2	2.2	5.4	0.49	0.23	0.57
306	306	4	2	1	2	1	8.0	2.2	5.3	0.55	0.09	0.58
307	307	4	2	1	2	1	8.2	2.6	4.7	0.55	0.14	0.68
308	308	4	2	1	2	1	9.2	2.3	5.2	0.43	0.08	0.74
309	309	4	2	1	2	1	7.8	2.3	3.8	0.23	0.08	0.61
310	310	4	2	1	2	1	9.3	2.4	5.1	0.50	0.11	0.51
311	311	4	2	1	2	2	8.4	1.9	4.1	0.52	0.31	0.65
312	312	4	2	1	2	2	8.2	2.2	5.3	0.65	0.07	0.55
313	313	4	2	1	2	2	8.1	2.2	5.3	0.39	0.07	0.61
314	314	4	2	1	2	2	8.2	2.3	4.5	0.32	0.07	0.66
315	315	4	2	1	2	2	8.4	2.2	4.1	0.28	0.13	0.38
316	316	4	2	1	2	2	8.1	2.4	3.9	0.55	0.13	0.52
317	317	4	2	1	2	2	8.0	2.4	5.6	0.56	0.13	0.47

PLASMA DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	CLASS	P_CA	P_MG	P_P	P_CU	P_SE	P_ZN
318	318	4	2	1	2	2	7.6	1.9	4.0	0.68	0.07	0.56
319	319	4	2	1	2	2	8.1	2.2	5.6	0.60	0.11	0.45
320	320	4	2	1	2	2	8.1	2.2	5.2	0.29	0.13	0.43
321	321	4	2	1	3	1	8.4	2.5	5.4	0.31	0.10	0.75
322	322	4	2	1	3	1	8.4	2.4	5.9	0.43	0.17	0.68
323	323	4	2	1	3	1	9.1	2.9	8.0	0.45	0.13	0.92
324	324	4	2	1	3	1	9.2	2.8	4.0	0.55	0.15	0.65
325	325	4	2	1	3	1	8.3	2.4	2.7	0.51	0.15	0.11
326	326	4	2	1	3	1	8.2	2.0	5.9	0.36	0.11	0.73
327	327	4	2	1	3	1	7.8	2.9	6.1	0.29	0.11	0.78
328	328	4	2	1	3	1	8.4	2.8	5.6	0.30	0.11	0.84
329	329	4	2	1	3	1	8.2	2.7	5.6	0.38	0.10	0.80
330	330	4	2	1	3	1	8.2	2.8	3.0	0.39	0.10	0.76
331	331	4	2	1	3	2	7.8	2.7	7.9	0.29	0.17	0.78
332	332	4	2	1	3	2	7.9	2.9	5.7	0.54	0.09	0.73
333	333	4	2	1	3	2	7.6	2.7	4.8	0.44	0.17	0.74
334	334	4	2	1	3	2	7.8	2.7	3.8	0.43	0.09	0.53
335	335	4	2	1	3	2	9.1	2.8	5.7	0.44	0.16	0.73
336	336	4	2	1	3	2	7.6	3.1	4.2	0.32	0.21	0.59
337	337	4	2	1	3	2	7.9	3.3	8.8	0.52	0.11	1.06
338	338	4	2	1	3	2	7.7	2.6	4.9	0.42	0.10	0.94
339	339	4	2	1	3	2	8.1	2.5	4.2	0.32	0.17	0.72
340	340	4	2	1	3	2	8.1	2.7	3.9	0.25	0.10	0.77
341	341	4	2	1	4	1	8.2	2.5	6.0	0.54	0.14	0.65
342	342	4	2	1	4	1	9.2	2.7	4.5	0.26	0.14	0.52
343	343	4	2	1	4	1	7.9	2.2	5.4	0.11	0.11	0.53
344	344	4	2	1	4	1	9.6	2.3	4.7	0.27	0.11	0.41
345	345	4	2	1	4	1	10.2	2.3	5.3	0.11	0.12	0.45
346	346	4	2	1	4	1	8.7	2.5	5.0	0.47	0.10	0.30
347	347	4	2	1	4	1	7.7	2.3	6.9	0.27	0.17	0.23
348	348	4	2	1	4	1	8.4	2.4	4.4	0.31	0.10	0.61
349	349	4	2	1	4	1	9.4	2.3	3.0	0.45	0.10	0.48
350	350	4	2	1	4	1	10.0	2.4	3.7	0.66	0.15	0.58
351	351	4	2	1	4	2	9.1	2.7	6.8	0.20	0.14	0.56
352	352	4	2	1	4	2	8.4	2.7	4.8	0.26	0.14	0.50
353	353	4	2	1	4	2	7.8	2.1	5.3	0.12	0.14	0.38
354	354	4	2	1	4	2	8.4	2.3	5.1	0.28	0.10	0.31
355	355	4	2	1	4	2	8.6	2.4	5.9	0.32	0.10	0.31
356	356	4	2	1	4	2	9.2	2.5	5.2	0.44	0.10	0.30
357	357	4	2	1	4	2	9.2	2.4	6.7	0.29	0.13	0.27
358	358	4	2	1	4	2	7.8	2.4	4.1	0.27	0.15	0.47
359	359	4	2	1	4	2	8.0	2.4	2.7	0.43	0.11	0.20
360	360	4	2	1	4	2	8.4	2.3	6.0	0.78	0.15	0.80
361	361	4	2	2	5	1	8.9	2.0	5.2	0.74	0.03	0.66
362	362	4	2	2	5	1	9.0	2.5	5.8	0.68	0.07	0.80
363	363	4	2	2	5	1	8.7	2.3	6.7	0.56	0.03	0.98
364	364	4	2	2	5	1	8.8	2.4	6.6	0.73	0.01	0.91
365	365	4	2	2	5	1	8.3	2.5	6.9	0.67	0.03	0.86
366	366	4	2	2	5	1	8.2	2.6	6.5	1.04	0.02	0.73
367	367	4	2	2	5	1	8.3	2.7	5.1	0.73	0.07	1.07
368	368	4	2	2	5	1	8.4	2.5	5.1	0.60	0.01	0.78
369	369	4	2	2	5	1	8.4	2.6	5.3	0.48	0.01	0.86
370	370	4	2	2	5	1	8.1	2.2	6.2	0.78	0.03	0.87
371	371	4	2	2	5	2	7.8	2.4	4.8	0.85	0.02	0.89
372	372	4	2	2	5	2	8.0	2.1	5.7	0.87	0.02	0.86
373	373	4	2	2	5	2	8.2	2.4	7.0	0.63	0.06	1.03
374	374	4	2	2	5	2	8.5	2.4	7.2	1.15	0.01	1.33
375	375	4	2	2	5	2	9.1	2.5	6.8	1.13	0.03	1.39
376	376	4	2	2	5	2	9.3	2.5	6.3	0.79	0.03	0.80
377	377	4	2	2	5	2	8.4	2.7	5.1	0.70	0.05	0.98
378	378	4	2	2	5	2	7.9	2.6	4.6	0.45	0.01	0.80
379	379	4	2	2	5	2	8.3	2.7	5.2	0.52	0.01	1.00
380	380	4	2	2	5	2	8.4	2.3	5.9	0.79	0.02	0.90
381	381	4	2	2	6	1	8.3	2.3	5.4	0.63	0.03	0.83

PLASMA DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	CLASS	P_CA	P_MG	P_P	P_CU	P_SE	P_ZN
382	382	4	2	2	6	1	8.7	2.4	5.2	0.71	0.02	0.93
383	383	4	2	2	6	1	8.1	2.8	5.3	0.65	0.01	1.01
384	384	4	2	2	6	1	7.7	2.3	6.7	0.61	0.01	0.87
385	385	4	2	2	6	1	8.7	2.4	6.9	0.64	0.03	0.88
386	386	4	2	2	6	1	8.4	2.1	4.7	0.73	0.03	0.80
387	387	4	2	2	6	1	8.2	2.6	6.3	0.74	0.03	0.89
388	388	4	2	2	6	1	8.1	2.3	5.2	0.67	0.02	0.77
389	389	4	2	2	6	1	8.0	2.5	5.7	0.69	0.06	0.93
390	390	4	2	2	6	1	8.6	2.4	7.0	0.60	0.04	0.90
391	391	4	2	2	6	2	8.5	2.3	4.7	0.71	0.03	0.87
392	392	4	2	2	6	2	8.3	2.6	5.8	0.72	0.02	1.03
393	393	4	2	2	6	2	8.4	2.1	5.3	0.63	0.03	0.90
394	394	4	2	2	6	2	8.6	2.7	6.1	0.64	0.02	0.87
395	395	4	2	2	6	2	8.7	2.4	6.8	0.65	0.02	0.78
396	396	4	2	2	6	2	8.8	2.3	5.1	0.68	0.01	0.79
397	397	4	2	2	6	2	8.3	2.2	5.3	0.57	0.01	0.83
398	398	4	2	2	6	2	8.9	2.4	6.3	0.52	0.01	0.81
399	399	4	2	2	6	2	9.8	2.5	6.0	0.63	0.03	0.87
400	400	4	2	2	6	2	8.7	2.3	5.1	0.67	0.02	0.83
401	401	4	2	2	7	1	9.1	3.0	2.2	0.62	0.14	0.96
402	402	4	2	2	7	1	9.1	3.2	3.9	0.76	0.03	0.82
403	403	4	2	2	7	1	9.1	2.6	3.6	0.78	0.04	1.01
404	404	4	2	2	7	1	8.3	2.6	3.8	0.78	0.04	1.04
405	405	4	2	2	7	1	8.4	3.1	3.8	0.92	0.08	0.69
406	406	4	2	2	7	1	8.6	3.0	2.2	0.70	0.05	0.85
407	407	4	2	2	7	1	8.4	2.7	4.4	0.72	0.05	1.00
408	408	4	2	2	7	1	8.3	2.8	4.7	0.60	0.09	0.78
409	409	4	2	2	7	1	7.9	2.5	2.4	0.69	0.14	0.85
410	410	4	2	2	7	1	8.4	2.6	2.4	0.79	0.05	0.84
411	411	4	2	2	7	2	8.4	3.0	2.7	0.80	0.04	0.87
412	412	4	2	2	7	2	8.7	3.2	4.1	0.67	0.15	0.78
413	413	4	2	2	7	2	7.8	2.6	3.8	0.68	0.05	0.59
414	414	4	2	2	7	2	7.7	2.7	3.6	0.61	0.06	0.54
415	415	4	2	2	7	2	8.4	3.2	3.6	0.69	0.09	0.62
416	416	4	2	2	7	2	8.4	3.1	2.6	0.58	0.07	0.72
417	417	4	2	2	7	2	7.8	2.8	4.2	0.69	0.07	0.85
418	418	4	2	2	7	2	8.9	2.8	4.3	0.68	0.07	0.63
419	419	4	2	2	7	2	8.4	2.8	2.5	0.72	0.03	0.63
420	420	4	2	2	7	2	8.4	3.1	2.5	0.70	0.06	0.58
421	421	4	2	2	8	1	9.1	2.5	3.9	0.86	0.03	0.34
422	422	4	2	2	8	1	9.4	2.6	4.2	0.88	0.03	0.32
423	423	4	2	2	8	1	9.5	2.9	4.8	0.52	0.05	0.34
424	424	4	2	2	8	1	9.5	3.0	5.1	0.90	0.09	0.41
425	425	4	2	2	8	1	9.2	2.6	2.9	0.61	0.03	0.40
426	426	4	2	2	8	1	9.1	2.8	3.2	0.50	0.03	0.39
427	427	4	2	2	8	1	8.4	2.2	4.7	0.80	0.03	0.37
428	428	4	2	2	8	1	9.2	2.8	4.2	0.79	0.04	0.45
429	429	4	2	2	8	1	8.4	2.8	3.7	0.61	0.04	0.35
430	430	4	2	2	8	1	8.4	2.3	3.3	0.73	0.04	0.31
431	431	4	2	2	8	2	10.2	2.3	3.6	0.66	0.05	0.36
432	432	4	2	2	8	2	9.8	2.5	4.2	0.84	0.05	0.67
433	433	4	2	2	8	2	9.3	2.7	4.7	0.86	0.05	0.70
434	434	4	2	2	8	2	8.9	2.4	5.3	0.94	0.05	0.71
435	435	4	2	2	8	2	8.4	2.7	3.0	0.95	0.05	0.79
436	436	4	2	2	8	2	9.2	2.0	3.6	0.90	0.05	0.69
437	437	4	2	2	8	2	8.9	2.7	4.1	0.87	0.04	0.64
438	438	4	2	2	8	2	9.0	2.6	3.8	0.86	0.17	0.79
439	439	4	2	2	8	2	8.3	2.2	4.1	0.72	0.06	0.60
440	440	4	2	2	8	2	9.1	2.2	3.3	0.82	0.04	0.60
441	441	4	2	3	9	1	8.1	2.3	7.1	0.73	0.07	0.59
442	442	4	2	3	9	1	8.4	2.8	5.9	0.73	0.06	0.55
443	443	4	2	3	9	1	8.2	1.8	4.0	0.62	0.01	0.76
444	444	4	2	3	9	1	8.9	2.8	4.2	0.61	0.03	0.49

PLASMA DATA

OBS	SAMPLE	TYPE	SEASON	REGICN	FARM	CLASS	P_CA	P_MG	P_P	P_CU	P_SE	P_ZN
445	445	4	2	3	9	1	8.4	1.7	3.2	0.63	0.02	0.74
446	446	4	2	3	9	1	8.4	2.0	5.3	0.60	0.02	0.51
447	447	4	2	3	9	1	7.9	2.8	7.2	0.60	0.01	0.65
448	448	4	2	3	9	1	8.9	1.7	5.4	0.64	0.02	0.55
449	449	4	2	3	9	1	9.2	2.6	5.6	0.60	0.03	0.78
450	450	4	2	3	9	1	9.2	2.6	6.3	0.63	0.02	0.72
451	451	4	2	3	9	2	8.5	2.6	8.2	0.62	0.02	0.51
452	452	4	2	3	9	2	8.4	2.4	8.2	0.62	0.02	0.32
453	453	4	2	3	9	2	9.2	2.9	8.1	0.65	0.01	0.45
454	454	4	2	3	9	2	8.4	2.9	8.3	0.60	0.01	0.77
455	455	4	2	3	9	2	7.9	2.4	8.1	0.80	0.01	0.65
456	456	4	2	3	9	2	7.9	2.7	8.0	0.60	0.01	0.74
457	457	4	2	3	9	2	9.1	2.4	8.0	0.69	0.02	0.77
458	458	4	2	3	9	2	8.4	2.4	7.9	0.69	0.02	0.85
459	459	4	2	3	9	2	8.4	2.9	8.2	0.70	0.02	0.72
460	460	4	2	3	9	2	8.6	3.0	8.0	0.76	0.03	0.73
461	461	4	2	3	10	1	7.8	2.7	4.8	0.66	0.03	0.61
462	462	4	2	3	10	1	9.1	2.4	4.6	0.50	0.02	0.77
463	463	4	2	3	10	1	9.2	2.8	3.2	0.55	0.02	0.93
464	464	4	2	3	10	1	8.4	2.9	4.6	0.67	0.02	0.95
465	465	4	2	3	10	1	8.3	2.5	3.3	0.66	0.02	0.61
466	466	4	2	3	10	1	8.6	2.5	3.3	0.55	0.02	0.69
467	467	4	2	3	10	1	8.4	2.6	4.5	0.66	0.01	0.78
468	468	4	2	3	10	1	8.4	2.8	5.1	0.81	0.03	0.67
469	469	4	2	3	10	1	8.2	2.8	4.5	0.67	0.03	0.49
470	470	4	2	3	10	1	8.2	2.3	3.7	0.73	0.02	0.64
471	471	4	2	3	10	2	8.4	2.4	7.5	0.60	0.01	0.90
472	472	4	2	3	10	2	8.6	2.5	5.8	0.83	0.01	0.63
473	473	4	2	3	10	2	8.7	3.0	5.2	0.69	0.03	0.69
474	474	4	2	3	10	2	8.3	2.8	5.4	0.76	0.03	0.61
475	475	4	2	3	10	2	8.3	2.7	5.6	0.77	0.01	0.52
476	476	4	2	3	10	2	8.8	3.4	8.0	0.63	0.03	0.55
477	477	4	2	3	10	2	8.6	3.0	5.9	0.62	0.02	0.46
478	478	4	2	3	10	2	8.4	2.5	5.4	0.63	0.01	0.75
479	479	4	2	3	10	2	8.4	2.2	4.7	0.49	0.01	0.65
480	480	4	2	3	10	2	8.4	2.5	5.7	0.70	0.01	0.80
481	481	4	2	3	11	1	9.1	2.6	1.9	0.79	0.07	0.82
482	482	4	2	3	11	1	8.6	2.7	3.4	0.89	0.08	0.82
483	483	4	2	3	11	1	8.3	2.7	3.8	0.71	0.08	0.83
484	484	4	2	3	11	1	9.1	2.6	3.2	0.94	0.08	0.87
485	485	4	2	3	11	1	8.4	2.5	4.5	0.65	0.07	0.79
486	486	4	2	3	11	1	9.4	2.1	4.4	0.82	0.06	0.70
487	487	4	2	3	11	1	10.0	2.3	4.8	0.71	0.07	0.89
488	488	4	2	3	11	1	8.3	2.3	3.8	0.66	0.07	0.59
489	489	4	2	3	11	1	8.6	2.5	2.5	0.73	0.06	0.69
490	490	4	2	3	11	1	7.6	2.4	4.1	0.70	0.06	0.65
491	491	4	2	3	11	2	8.1	2.6	2.5	0.88	0.07	0.64
492	492	4	2	3	11	2	7.9	2.6	3.0	0.74	0.07	0.70
493	493	4	2	3	11	2	9.0	2.6	3.6	0.56	0.07	0.77
494	494	4	2	3	11	2	7.4	2.6	2.5	0.72	0.10	0.64
495	495	4	2	3	11	2	7.9	2.5	4.1	0.60	0.07	0.78
496	496	4	2	3	11	2	8.2	2.0	4.5	0.69	0.06	0.53
497	497	4	2	3	11	2	8.3	2.1	4.2	0.58	0.06	0.66
498	498	4	2	3	11	2	8.5	2.2	3.6	0.60	0.08	0.42
499	499	4	2	3	11	2	8.4	2.4	2.9	0.53	0.06	0.66
500	500	4	2	3	11	1	8.6	2.4	2.4	0.54	0.06	0.67
501	501	4	2	3	12	1	7.9	2.6	3.2	0.75	0.03	1.39
502	502	4	2	3	12	1	7.8	2.3	4.4	0.71	0.07	1.21
503	503	4	2	3	12	1	9.2	2.5	3.6	0.80	0.03	1.02
504	504	4	2	3	12	1	9.1	2.7	3.2	0.79	0.03	1.12
505	505	4	2	3	12	1	9.0	2.5	5.6	0.79	0.07	1.47
506	506	4	2	3	12	1	8.9	2.3	4.0	0.61	0.09	1.02
507	507	4	2	3	12	1	8.6	2.6	1.7	0.62	0.12	0.97
508	508	4	2	3	12	1	8.9	2.6	2.1	0.50	0.09	0.97

PLASMA DATA

OBS	SAMPLE	TYPE	SEASON	REGICN	FARM	CLASS	P_CA	P_MG	P_P	P_CU	P_SE	P_ZN
509	509	4	2	3	12	1	9.1	2.9	4.1	0.53	0.04	1.38
510	510	4	2	3	12	1	8.1	2.4	3.8	0.58	0.03	0.99
511	511	4	2	3	12	2	7.6	2.3	4.9	0.74	0.04	1.08
512	512	4	2	3	12	2	7.9	2.1	4.8	0.76	0.04	0.91
513	513	4	2	3	12	2	7.3	2.6	4.6	0.66	0.04	1.06
514	514	4	2	3	12	2	7.6	2.6	5.7	0.72	0.05	1.05
515	515	4	2	3	12	2	9.1	2.2	4.9	0.96	0.04	1.07
516	516	4	2	3	12	2	8.3	2.3	3.4	0.65	0.07	0.98
517	517	4	2	3	12	2	8.2	2.1	4.0	0.54	0.04	1.13
518	518	4	2	3	12	2	8.1	2.4	3.9	0.60	0.04	0.92
519	519	4	2	3	12	2	8.1	2.2	5.3	0.69	0.05	1.11
520	520	4	2	3	12	2	7.9	2.3	5.9	0.63	0.04	1.00
521	521	4	2	3	13	1	8.3	2.7	4.8	0.88	0.04	0.64
522	522	4	2	3	13	1	8.4	2.7	6.3	0.63	0.04	0.82
523	523	4	2	3	13	1	9.3	2.8	4.9	0.64	0.05	0.77
524	524	4	2	3	13	1	9.2	2.6	4.8	0.68	0.04	0.77
525	525	4	2	3	13	1	9.1	3.0	4.7	0.76	0.11	0.80
526	526	4	2	3	13	1	8.3	2.8	4.5	0.63	0.03	0.63
527	527	4	2	3	13	1	8.2	2.5	5.5	0.67	0.02	0.76
528	528	4	2	3	13	1	8.2	2.6	4.2	0.60	0.04	0.86
529	529	4	2	3	13	1	8.1	2.5	5.9	0.67	0.06	0.83
530	530	4	2	3	13	1	8.4	2.4	7.0	0.82	0.06	0.73
531	531	4	2	3	13	2	8.7	2.7	5.3	0.67	0.04	0.67
532	532	4	2	3	13	2	9.1	2.6	6.7	0.67	0.06	0.78
533	533	4	2	3	13	2	8.3	2.7	4.4	0.91	0.04	0.68
534	534	4	2	3	13	2	8.7	2.6	5.1	0.63	0.07	0.70
535	535	4	2	3	13	2	8.9	3.0	4.8	0.67	0.04	0.77
536	536	4	2	3	13	2	8.2	2.8	4.6	0.67	0.04	0.64
537	537	4	2	3	13	2	8.1	2.3	6.1	0.72	0.04	0.78
538	538	4	2	3	13	2	7.8	2.4	3.8	0.74	0.06	0.76
539	539	4	2	3	13	2	9.2	2.6	6.1	0.87	0.04	0.57
540	540	4	2	3	13	2	8.2	2.4	6.3	0.87	0.11	0.55
541	541	4	2	3	14	1	8.0	2.5	4.8	0.84	0.07	1.09
542	542	4	2	3	14	1	8.2	2.3	5.8	0.45	0.09	0.98
543	543	4	2	3	14	1	8.4	2.6	5.0	0.86	0.09	0.99
544	544	4	2	3	14	1	7.8	2.4	5.8	0.76	0.09	0.91
545	545	4	2	3	14	1	9.1	2.2	6.5	0.72	0.15	0.96
546	546	4	2	3	14	1	9.1	2.2	5.4	0.55	0.07	0.79
547	547	4	2	3	14	1	8.9	2.1	6.9	0.37	0.10	0.73
548	548	4	2	3	14	1	8.7	1.9	6.4	0.22	0.08	0.85
549	549	4	2	3	14	1	9.1	1.9	7.4	0.43	0.10	0.65
550	550	4	2	3	14	1	8.4	2.2	5.1	0.55	0.10	0.79
551	551	4	2	3	14	2	8.6	2.2	5.5	0.76	0.04	0.68
552	552	4	2	3	14	2	8.1	2.8	7.3	0.32	0.04	1.25
553	553	4	2	3	14	2	8.1	2.1	5.5	0.49	0.02	0.85
554	554	4	2	3	14	2	7.8	2.1	4.8	0.76	0.04	0.59
555	555	4	2	3	14	2	7.7	2.3	5.7	0.73	0.07	0.58
556	556	4	2	3	14	2	7.4	2.4	5.7	0.46	0.06	0.85
557	557	4	2	3	14	2	8.9	2.3	5.4	0.72	0.06	0.65
558	558	4	2	3	14	2	8.9	2.4	4.6	0.95	0.03	0.78
559	559	4	2	3	14	2	8.8	2.1	5.7	0.45	0.05	0.92
560	560	4	2	3	14	2	8.4	2.1	5.8	0.47	0.07	0.43

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                                                  BONE DATA

 OBS   SAMPLE   TYPE   SEASON   REGION   FARM   CLASS    CA     MG      P     ASH    GRAVITY

   1      1       5       1        1       1      1     21.9   0.41   10.1   59.8     1.87
   2      2       5       1        1       1      1     21.6   0.67    9.5   61.9     1.75
   3      3       5       1        1       2      1     23.3   0.42   10.4   64.8     1.81
   4      4       5       1        1       2      1     22.9   0.47    9.5   63.1     1.70
   5      5       5       1        1       3      1     22.0   0.39   10.7   64.0     1.86
   6      6       5       1        1       3      1     22.0   0.37    9.8   64.2     1.69
   7      7       5       1        1       4      1     23.1   0.46   10.2   64.5     1.93
   8      8       5       1        1       4      1     23.2   0.44   10.4   63.2     1.79
   9      9       5       1        2       5      1     22.9   0.51   10.2   62.2     1.83
  10     10       5       1        2       5      1     22.4   0.49   10.1   60.1     1.56
  11     11       5       1        2       6      1     22.4   0.49   10.7   62.0     1.81
  12     12       5       1        2       6      1     23.4   0.48   10.4   63.3     1.69
  13     13       5       1        2       7      1     22.4   0.52   10.1   62.1     1.61
  14     14       5       1        2       7      1     22.4   0.51   10.4   63.4     1.63
  15     15       5       1        2       8      1     22.4   0.49   10.4   62.1     1.71
  16     16       5       1        2       8      1     23.7   0.53   10.6   63.3     1.68
  17     17       5       1        3       9      1     22.5   0.41   10.5   60.6     1.77
  18     18       5       1        3       9      1     23.7   0.49   10.7   60.7     1.59
  19     19       5       1        3      10      1     18.8   0.42    8.4   59.3     1.51
  20     20       5       1        3      10      1     22.0   0.46    9.7   59.6     1.45
  21     21       5       1        3      11      1     22.5   0.52   10.2   63.1     1.66
  22     22       5       1        3      11      1     20.9   0.48    9.5   63.5     1.67
  23     23       5       1        3      12      1     22.6   0.54   10.0   62.6     1.69
  24     24       5       1        3      12      1     22.5   0.52    9.9   62.3     1.73
  25     25       5       1        3      13      1     22.4   0.46    9.8   60.7     1.57
  26     26       5       1        3      13      1     23.5   0.55    9.8   62.4     1.88
  27     27       5       1        3      14      1     23.8   0.54   10.0   60.8     1.91
  28     28       5       1        3      14      1     27.0   0.61   12.1   63.4     1.71
  29     29       5       2        1       1      1     21.5   0.45    9.7   61.1     1.69
  30     30       5       2        1       1      1     22.3   0.47   10.0   62.8     1.80
  31     31       5       2        1       2      1     21.9   0.43   10.0   62.3     1.77
  32     32       5       2        1       2      1     22.1   0.40    9.8   62.6     1.83
  33     33       5       2        1       3      1     24.1   0.38   10.2   64.8     1.99
  34     34       5       2        1       3      1     25.3   0.39   11.0   67.9     2.01
  35     35       5       2        1       4      1     22.0   0.44   10.8   61.0     1.84
  36     36       5       2        1       4      1     21.3   0.38    9.3   58.9     1.90
  37     37       5       2        2       5      1     22.6   0.41   10.4   65.6     1.82
  38     38       5       2        2       5      1     25.4   0.38    9.6   67.4     1.92
  39     39       5       2        2       6      1     21.4   0.45    9.3   60.3     1.84
  40     40       5       2        2       6      1     22.2   0.47    9.4   61.5     1.93
  41     41       5       2        2       7      1     22.4   0.32    9.5   64.9     1.89
  42     42       5       2        2       7      1     23.5   0.38   10.6   65.2     1.83
  43     43       5       2        2       8      1     25.1   0.40   11.1   68.4     2.31
  44     44       5       2        2       8      1     24.9   0.39   11.1   66.3     2.16
  45     45       5       2        3       9      1     21.5   0.36    8.6   66.0     1.84
  46     46       5       2        3       9      1     24.0   0.34    9.4   65.1     1.73
  47     47       5       2        3      10      1     25.3   0.59   12.9   64.2     1.64
  48     48       5       2        3      10      1     26.5   0.39   12.9   72.8     1.91
  49     49       5       2        3      11      1     22.5   0.33   10.3   64.3     1.73
  50     50       5       2        3      11      1     23.7   0.35   10.4   65.5     1.89
  51     51       5       2        3      12      1     24.5   0.38   10.3   65.5     2.06
  52     52       5       2        3      12      1     21.5   0.36    9.3   58.7     1.56
  53     53       5       2        3      13      1     22.1   0.40   10.0   62.2     1.85
  54     54       5       2        3      13      1     23.0   0.44   11.4   63.0     1.91
  55     55       5       2        3      14      1     25.4   0.36    9.3   67.9     1.92
  56     56       5       2        3      14      1     25.4   0.33    9.4   67.4     1.97
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                                                  LIVER DATA

 OBS  SAMPLE   TYPE  SEASON   REGION    FARM   CLASS     L_CD    L_CU    L_FE    L_MN    L_MO    L_ZN    L_SE

   1       1      3       1        1       1       1     0.51     165     474     3.7    2.87     119       .
   2       2      3       1        1       1       1     0.38     151     497    14.9    2.35     112       .
   3       3      3       1        1       1       1     0.46     319     418    17.2    2.80     119       .
   4       4      3       1        1       1       1     0.47     290     364    13.6    1.67     143       .
   5       5      3       1        1       1       1     0.35     122     483     8.5    3.41     129       .
   6       6      3       1        1       1       1     0.50     218     531    13.9    5.08     153       .
   7       7      3       1        1       1       1        .       .       .       .       .       .    1.50
   8       8      3       1        1       1       1        .       .       .       .       .       .    0.92
   9       9      3       1        1       1       1        .       .       .       .       .       .    1.94
  10      10      3       1        1       1       1        .       .       .       .       .       .    2.40
  11      11      3       1        1       1       2     0.36     174     332    14.4    3.68     145       .
  12      12      3       1        1       1       2     0.32     126     289     9.0    1.15     109       .
  13      13      3       1        1       1       2     0.27     108     197    11.3    3.17     130       .
  14      14      3       1        1       1       2     0.47     193     305    13.9    3.47     124       .
  15      15      3       1        1       1       2     0.25     129     215     8.9    3.75     112       .
  16      16      3       1        1       1       2     0.44     187     213    13.3    1.98     129       .
  17      17      3       1        1       1       2        .       .       .       .       .       .    0.96
  18      18      3       1        1       1       2        .       .       .       .       .       .    1.62
  19      19      3       1        1       1       2        .       .       .       .       .       .    1.80
  20      20      3       1        1       1       2        .       .       .       .       .       .    0.86
  21      21      3       1        1       2       1     0.48      35     460     8.3    4.49     101       .
  22      22      3       1        1       2       1     0.49      28     729     5.4    4.61     131       .
  23      23      3       1        1       2       1     0.53      40     836     9.3    4.31     102       .
  24      24      3       1        1       2       1     0.63      35     641    10.4    4.40      91       .
  25      25      3       1        1       2       1     0.57      22     618     8.3    4.61     103       .
  26      26      3       1        1       2       1     0.58      15     400    11.4    4.73      92       .
  27      27      3       1        1       2       1        .       .       .       .       .       .    0.96
  28      28      3       1        1       2       1        .       .       .       .       .       .    1.64
  29      29      3       1        1       2       1        .       .       .       .       .       .    0.86
  30      30      3       1        1       2       1        .       .       .       .       .       .    1.24
  31      31      3       1        1       2       2     0.59      20     364     8.1    4.21      94       .
  32      32      3       1        1       2       2     0.47      20     450     7.3    4.25      90       .
  33      33      3       1        1       2       2     0.49      28     178     6.4    4.31      91       .
  34      34      3       1        1       2       2     0.33      29     243     7.3    4.33      90       .
  35      35      3       1        1       2       2     0.29      30     181     5.3    4.17      88       .
  36      36      3       1        1       2       2     0.43      50     310     6.9    4.40      91       .
  37      37      3       1        1       2       2        .       .       .       .       .       .    0.75
  38      38      3       1        1       2       2        .       .       .       .       .       .    0.90
  39      39      3       1        1       2       2        .       .       .       .       .       .    0.83
  40      40      3       1        1       2       2        .       .       .       .       .       .    0.92
  41      41      3       1        1       3       1     0.78      23     521     8.3    3.16     112       .
  42      42      3       1        1       3       1     0.49      14     956     4.7    4.87     141       .
  43      43      3       1        1       3       1     0.51      14     976     9.7    6.40      90       .
  44      44      3       1        1       3       1     0.45      13     836     9.4    5.07      89       .
  45      45      3       1        1       3       1     0.49      15     965     8.5    4.24     103       .
  46      46      3       1        1       3       1     0.62      12     615    12.0    2.56      95       .
  47      47      3       1        1       3       1        .       .       .       .       .       .    3.35
  48      48      3       1        1       3       1        .       .       .       .       .       .    5.00
  49      49      3       1        1       3       1        .       .       .       .       .       .    2.76
  50      50      3       1        1       3       1        .       .       .       .       .       .    2.40
  51      51      3       1        1       3       2     0.43      13     401     8.6    3.13      92       .
  52      52      3       1        1       3       2     0.26      12     365     7.6    4.39      92       .
  53      53      3       1        1       3       2     0.44      17     375     7.0    4.61      94       .
  54      54      3       1        1       3       2     0.68      31     451     7.0    3.06      91       .
  55      55      3       1        1       3       2     0.51      19     175     7.3    3.40     103       .
  56      56      3       1        1       3       2     0.31      15     244     6.1    3.19      96       .
  57      57      3       1        1       3       2        .       .       .       .       .       .    2.40
  58      58      3       1        1       3       2        .       .       .       .       .       .    2.81
  59      59      3       1        1       3       2        .       .       .       .       .       .    2.53
  60      60      3       1        1       3       2        .       .       .       .       .       .    3.49
  61      61      3       1        1       4       1     0.30      33     270     2.3    1.40      86       .
  62      62      3       1        1       4       1     0.38      42     325    10.6    3.10     119       .
  63      63      3       1        1       4       1     0.61      66     337     2.6    3.77     143       .
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LIVER DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	CLASS	L_CO	L_CU	L_FE	L_MN	L_MO	L_ZN	L_SE
64	64	3	1	1	4	1	0.34	50	424	9.3	3.62	111	.
65	65	3	1	1	4	1	0.55	59	690	10.1	3.52	135	.
66	66	3	1	1	4	1	0.67	69	250	7.6	3.82	121	.
67	67	3	1	1	4	1	.	.	.	.	.	.	1.47
68	68	3	1	1	4	1	.	.	.	.	.	.	0.79
69	69	3	1	1	4	1	.	.	.	.	.	.	2.37
70	70	3	1	1	4	1	.	.	.	.	.	.	6.62
71	71	3	1	1	4	2	0.43	23	703	8.8	3.73	161	.
72	72	3	1	1	4	2	0.40	32	376	11.3	3.18	104	.
73	73	3	1	1	4	2	0.66	35	487	9.5	2.87	116	.
74	74	3	1	1	4	2	0.61	18	912	8.2	4.22	106	.
75	75	3	1	1	4	2	0.53	19	345	8.3	3.93	94	.
76	76	3	1	1	4	2	0.69	97	239	8.8	5.91	123	.
77	77	3	1	1	4	2	.	.	.	.	.	.	5.01
78	78	3	1	1	4	2	.	.	.	.	.	.	2.39
79	79	3	1	1	4	2	.	.	.	.	.	.	1.80
80	80	3	1	1	4	2	.	.	.	.	.	.	3.60
81	81	3	1	2	5	1	0.37	26	270	4.0	1.92	76	.
82	82	3	1	2	5	1	0.43	66	299	9.4	3.67	191	.
83	83	3	1	2	5	1	0.40	36	356	1.7	4.58	95	.
84	84	3	1	2	5	1	0.37	25	284	2.9	2.08	90	.
85	85	3	1	2	5	1	0.37	88	333	4.7	3.24	139	.
86	86	3	1	2	5	1	0.39	84	258	9.4	3.22	123	.
87	87	3	1	2	5	1	.	.	.	.	.	.	0.25
88	88	3	1	2	5	1	.	.	.	.	.	.	0.26
89	89	3	1	2	5	1	.	.	.	.	.	.	0.61
90	90	3	1	2	5	1	.	.	.	.	.	.	0.31
91	91	3	1	2	5	2	0.30	36	347	4.5	2.57	116	.
92	92	3	1	2	5	2	0.31	24	366	2.9	3.08	126	.
93	93	3	1	2	5	2	0.49	29	273	4.8	2.86	116	.
94	94	3	1	2	5	2	0.38	30	279	13.9	3.09	123	.
95	95	3	1	2	5	2	0.36	20	328	14.6	2.53	86	.
96	96	3	1	2	5	2	0.27	30	368	14.3	2.71	122	.
97	97	3	1	2	5	2	.	.	.	.	.	.	0.26
98	98	3	1	2	5	2	.	.	.	.	.	.	0.31
99	99	3	1	2	5	2	.	.	.	.	.	.	0.42
100	100	3	1	2	5	2	.	.	.	.	.	.	0.23
101	101	3	1	2	6	1	0.30	89	266	4.7	3.12	101	.
102	102	3	1	2	6	1	0.38	88	253	6.5	3.24	117	.
103	103	3	1	2	6	1	0.43	109	264	7.4	3.20	115	.
104	104	3	1	2	6	1	0.40	95	270	4.0	2.80	115	.
105	105	3	1	2	6	1	0.49	129	303	9.8	3.18	137	.
106	106	3	1	2	6	1	0.53	92	295	7.0	3.28	100	.
107	107	3	1	2	6	1	.	.	.	.	.	.	0.27
108	108	3	1	2	6	1	.	.	.	.	.	.	0.24
109	109	3	1	2	6	1	.	.	.	.	.	.	0.31
110	110	3	1	2	6	1	.	.	.	.	.	.	0.28
111	111	3	1	2	6	2	0.48	114	289	7.8	2.50	97	.
112	112	3	1	2	6	2	0.31	76	257	9.3	3.10	94	.
113	113	3	1	2	6	2	0.38	80	214	9.0	2.80	91	.
114	114	3	1	2	6	2	0.47	73	214	9.9	3.17	94	.
115	115	3	1	2	6	2	0.46	93	320	6.3	2.91	125	.
116	116	3	1	2	6	2	0.47	83	341	5.3	2.97	107	.
117	117	3	1	2	6	2	.	.	.	.	.	.	0.27
118	118	3	1	2	6	2	.	.	.	.	.	.	0.21
119	119	3	1	2	6	2	.	.	.	.	.	.	0.31
120	120	3	1	2	6	2	.	.	.	.	.	.	0.32
121	121	3	1	2	7	1	0.37	246	344	11.8	3.68	106	.
122	122	3	1	2	7	1	0.40	88	342	9.6	4.48	123	.
123	123	3	1	2	7	1	0.26	191	263	10.7	1.01	90	.
124	124	3	1	2	7	1	0.36	192	203	2.1	2.04	115	.
125	125	3	1	2	7	1	0.41	217	290	10.5	2.33	105	.
126	126	3	1	2	7	1	0.29	195	213	9.6	1.05	100	.

LIVER DATA

CBS	SAMPLE	TYPE	SEASON	REGION	FARM	CLASS	L_CO	L_CU	L_FE	L_MN	L_MC	L_ZN	L_SE
127	127	3	1	2	7	1	.	.	.	.	.	.	0.44
128	128	3	1	2	7	1	.	.	.	.	.	.	0.68
129	129	3	1	2	7	1	.	.	.	.	.	.	0.63
130	130	3	1	2	7	1	.	.	.	.	.	.	0.80
131	131	3	1	2	7	2	0.29	103	228	8.4	1.39	100	.
132	132	3	1	2	7	2	0.51	200	339	11.3	1.58	138	.
133	133	3	1	2	7	2	0.22	260	194	10.8	1.56	96	.
134	134	3	1	2	7	2	0.24	273	257	7.4	1.01	107	.
135	135	3	1	2	7	2	0.24	158	275	9.6	1.52	105	.
136	136	3	1	2	7	2	0.25	165	243	9.0	1.45	102	.
137	137	3	1	2	7	2	.	.	.	.	.	.	0.37
138	138	3	1	2	7	2	.	.	.	.	.	.	0.36
139	139	3	1	2	7	2	.	.	.	.	.	.	0.48
140	140	3	1	2	7	2	.	.	.	.	.	.	0.29
141	141	3	1	2	8	1	0.42	70	293	4.3	3.10	128	.
142	142	3	1	2	8	1	0.43	79	219	8.2	2.69	102	.
143	143	3	1	2	8	1	0.49	100	227	11.3	2.31	143	.
144	144	3	1	2	8	1	0.53	58	269	5.6	2.40	110	.
145	145	3	1	2	8	1	0.38	65	231	5.6	1.98	146	.
146	146	3	1	2	8	1	0.54	79	263	6.1	2.40	97	.
147	147	3	1	2	8	1	.	.	.	.	.	.	0.51
148	148	3	1	2	8	1	.	.	.	.	.	.	0.52
149	149	3	1	2	8	1	.	.	.	.	.	.	0.61
150	150	3	1	2	8	1	.	.	.	.	.	.	0.50
151	151	3	1	2	8	2	0.61	75	185	4.6	3.03	98	.
152	152	3	1	2	8	2	0.57	72	186	4.4	3.06	117	.
153	153	3	1	2	8	2	0.58	73	258	6.5	2.45	81	.
154	154	3	1	2	8	2	0.43	81	282	5.6	2.41	73	.
155	155	3	1	2	8	2	0.48	87	286	7.1	2.60	79	.
156	156	3	1	2	8	2	0.43	88	298	7.8	2.61	86	.
157	157	3	1	2	8	2	.	.	.	.	.	.	0.41
158	158	3	1	2	8	2	.	.	.	.	.	.	0.38
159	159	3	1	2	8	2	.	.	.	.	.	.	0.39
160	160	3	1	2	8	2	.	.	.	.	.	.	0.45
161	161	3	1	3	9	1	0.41	186	338	8.9	2.73	53	.
162	162	3	1	3	9	1	0.62	330	471	4.2	2.92	124	.
163	163	3	1	3	9	1	0.27	252	491	6.0	3.53	118	.
164	164	3	1	3	9	1	0.54	221	359	9.1	3.78	120	.
165	165	3	1	3	9	1	0.42	208	314	5.5	3.62	123	.
166	166	3	1	3	9	1	0.37	218	259	12.3	2.27	102	.
167	167	3	1	3	9	1	.	.	.	.	.	.	0.41
168	168	3	1	3	9	1	.	.	.	.	.	.	0.49
169	169	3	1	3	9	1	.	.	.	.	.	.	0.58
170	170	3	1	3	9	1	.	.	.	.	.	.	0.48
171	171	3	1	3	9	2	0.64	172	727	15.2	3.83	160	.
172	172	3	1	3	9	2	0.35	128	501	10.2	2.51	159	.
173	173	3	1	3	9	2	0.42	153	267	11.4	2.24	114	.
174	174	3	1	3	9	2	0.60	208	451	11.6	2.56	132	.
175	175	3	1	3	9	2	0.42	296	257	8.2	4.83	154	.
176	176	3	1	3	9	2	0.36	248	483	15.5	3.33	162	.
177	177	3	1	3	9	2	.	.	.	.	.	.	0.39
178	178	3	1	3	9	2	.	.	.	.	.	.	0.44
179	179	3	1	3	9	2	.	.	.	.	.	.	0.33
180	180	3	1	3	9	2	.	.	.	.	.	.	0.28
181	181	3	1	3	10	1	0.43	335	252	9.8	4.78	89	.
182	182	3	1	3	10	1	0.49	285	421	12.5	2.68	98	.
183	183	3	1	3	10	1	0.31	196	223	12.1	3.02	114	.
184	184	3	1	3	10	1	0.41	209	405	13.3	4.11	106	.
185	185	3	1	3	10	1	0.42	286	364	10.0	2.31	101	.
186	186	3	1	3	10	1	0.51	341	331	9.6	2.73	110	.
187	187	3	1	3	10	1	.	.	.	.	.	.	0.12
188	188	3	1	3	10	1	.	.	.	.	.	.	0.22
189	189	3	1	3	10	1	.	.	.	.	.	.	0.14

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                                                      LIVER DATA

OBS  SAMPLE  TYPE  SEASON  REGION  FARM  CLASS  L_CO  L_CU  L_FE  L_MN  L_MC  L_ZN  L_SE

190   190     3      1       3      10     1      .     .     .     .     .     .   0.27
191   191     3      1       3      10     2    0.43   169   279   3.3  4.69   146    .
192   192     3      1       3      10     2    0.31    92   327   8.0  2.47    95    .
193   193     3      1       3      10     2    1.10   134   439   4.2  2.19   130    .
194   194     3      1       3      10     2    0.78   241   646  10.1  5.02   100    .
195   195     3      1       3      10     2    1.12   247   691   9.8  3.17   121    .
196   196     3      1       3      10     2    0.35   134   274   6.4  3.77    93    .
197   197     3      1       3      10     2      .     .     .     .     .     .   0.23
198   198     3      1       3      10     2      .     .     .     .     .     .   0.20
199   199     3      1       3      10     2      .     .     .     .     .     .   0.29
200   200     3      1       3      10     2      .     .     .     .     .     .   0.21
201   201     3      1       3      11     1    0.21   107   242  10.7  2.75    94    .
202   202     3      1       3      11     1    0.42   115   309   9.0  5.87   107    .
203   203     3      1       3      11     1    0.89   202   978  12.5  4.22   116    .
204   204     3      1       3      11     1    0.32   150   231  12.1  2.33    86    .
205   205     3      1       3      11     1    0.30   119   210  10.3  3.63    87    .
206   206     3      1       3      11     1    0.38   148   251  13.4  3.45    92    .
207   207     3      1       3      11     1      .     .     .     .     .     .   1.31
208   208     3      1       3      11     1      .     .     .     .     .     .   0.90
209   209     3      1       3      11     1      .     .     .     .     .     .   0.81
210   210     3      1       3      11     1      .     .     .     .     .     .   0.87
211   211     3      1       3      11     2    0.43   175   258  10.6  4.14   124    .
212   212     3      1       3      11     2    0.46    73   333   8.9  5.83   118    .
213   213     3      1       3      11     2    0.31    89   235   6.5  4.99   111    .
214   214     3      1       3      11     2    0.36   128   265  10.0  4.50   101    .
215   215     3      1       3      11     2    0.62   138   398  14.0  5.50   119    .
216   216     3      1       3      11     2    0.50    80   232   4.9  4.15   106    .
217   217     3      1       3      11     2      .     .     .     .     .     .   0.69
218   218     3      1       3      11     2      .     .     .     .     .     .   0.81
219   219     3      1       3      11     2      .     .     .     .     .     .   0.77
220   220     3      1       3      11     2      .     .     .     .     .     .   0.79
221   221     3      1       3      12     1    0.42   123   430  12.4  5.06   126    .
222   222     3      1       3      12     1    0.30   105   216  10.5  3.14    91    .
223   223     3      1       3      12     1    0.36    34   300  12.3  1.84   109    .
224   224     3      1       3      12     1    0.42   129   253  10.8  3.18   122    .
225   225     3      1       3      12     1    0.57   100   400  11.9  2.61   136    .
226   226     3      1       3      12     1    0.41   102   348  10.9  4.69   100    .
227   227     3      1       3      12     1      .     .     .     .     .     .   0.50
228   228     3      1       3      12     1      .     .     .     .     .     .   0.58
229   229     3      1       3      12     1      .     .     .     .     .     .   0.69
230   230     3      1       3      12     1      .     .     .     .     .     .   0.78
231   231     3      1       3      12     2    0.42   111   294  12.4  2.27    94    .
232   232     3      1       3      12     2    0.42    61   610  12.2  3.70    99    .
233   233     3      1       3      12     2    0.56   101   381  13.7  4.97   114    .
234   234     3      1       3      12     2    0.44    74   351  14.2  4.91   105    .
235   235     3      1       3      12     2    0.42   164   292  12.3  4.20    98    .
236   236     3      1       3      12     2    0.37   148   303  15.6  4.57   109    .
237   237     3      1       3      12     2      .     .     .     .     .     .   0.71
238   238     3      1       3      12     2      .     .     .     .     .     .   0.68
239   239     3      1       3      12     2      .     .     .     .     .     .   0.67
240   240     3      1       3      12     2      .     .     .     .     .     .   0.90
241   241     3      1       3      13     1    0.69   166   253   7.6  2.61    91    .
242   242     3      1       3      13     1    0.43   322   391  11.7  2.87   108    .
243   243     3      1       3      13     1    0.42   236   356  13.2  3.32   116    .
244   244     3      1       3      13     1    0.79   182   330  11.5  4.98   105    .
245   245     3      1       3      13     1    0.67   216   432  12.2  4.09   155    .
246   246     3      1       3      13     1    0.41   379   467   3.7  3.74   153    .
247   247     3      1       3      13     1      .     .     .     .     .     .   0.40
248   248     3      1       3      13     1      .     .     .     .     .     .   0.28
249   249     3      1       3      13     1      .     .     .     .     .     .   0.37
250   250     3      1       3      13     1      .     .     .     .     .     .   0.39
251   251     3      1       3      13     2    0.49   127   274   8.1  3.08   128    .
252   252     3      1       3      13     2    0.97   354   324   3.8  1.15   154    .
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LIVER DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	CLASS	L_CO	L_CU	L_FE	L_MN	L_MO	L_ZN	L_SE
253	253	3	1	3	13	2	0.27	101	205	9.6	2.20	86	.
254	254	3	1	3	13	2	0.22	116	399	9.5	1.96	133	.
255	255	3	1	3	13	2	0.40	164	250	6.1	3.44	109	.
256	256	3	1	3	13	2	0.41	229	347	6.9	4.11	117	.
257	257	3	1	3	13	2	.	.	.	.	.	.	0.43
258	258	3	1	3	13	2	.	.	.	.	.	.	0.41
259	259	3	1	3	13	2	.	.	.	.	.	.	0.37
260	260	3	1	3	13	2	.	.	.	.	.	.	0.39
261	261	3	1	3	14	1	0.39	233	189	7.9	6.99	119	.
262	262	3	1	3	14	1	0.30	220	262	12.5	2.60	93	.
263	263	3	1	3	14	1	0.27	32	216	8.0	7.70	104	.
264	264	3	1	3	14	1	0.45	61	408	12.8	4.05	146	.
265	265	3	1	3	14	1	0.47	153	585	12.4	3.92	121	.
266	266	3	1	3	14	1	0.48	128	546	8.4	3.11	76	.
267	267	3	1	3	14	1	.	.	.	.	.	.	0.89
268	268	3	1	3	14	1	.	.	.	.	.	.	0.91
269	269	3	1	3	14	1	.	.	.	.	.	.	0.73
270	270	3	1	3	14	1	.	.	.	.	.	.	1.01
271	271	3	1	3	14	2	0.22	86	279	5.1	3.75	91	.
272	272	3	1	3	14	2	0.17	47	314	3.9	4.63	85	.
273	273	3	1	3	14	2	0.23	151	314	4.5	4.69	104	.
274	274	3	1	3	14	2	0.15	169	292	5.9	2.86	106	.
275	275	3	1	3	14	2	0.21	71	263	5.9	5.01	71	.
276	276	3	1	3	14	2	0.35	59	324	4.6	4.43	101	.
277	277	3	1	3	14	2	.	.	.	.	.	.	1.10
278	278	3	1	3	14	2	.	.	.	.	.	.	1.41
279	279	3	1	3	14	2	.	.	.	.	.	.	0.93
280	280	3	1	3	14	2	.	.	.	.	.	.	0.92
281	281	3	2	1	1	1	0.50	25	848	11.5	4.18	121	.
282	282	3	2	1	1	1	0.53	17	514	14.6	2.92	133	.
283	283	3	2	1	1	1	0.48	36	541	14.2	2.61	104	.
284	284	3	2	1	1	1	0.60	30	388	12.1	4.31	93	.
285	285	3	2	1	1	1	0.57	50	789	14.7	3.55	121	.
286	286	3	2	1	1	1	0.52	23	951	11.6	4.37	117	.
287	287	3	2	1	1	1	.	.	.	.	.	.	2.50
288	288	3	2	1	1	1	.	.	.	.	.	.	2.03
289	289	3	2	1	1	1	.	.	.	.	.	.	4.48
290	290	3	2	1	1	1	.	.	.	.	.	.	2.35
291	291	3	2	1	1	2	0.47	35	494	13.1	4.90	106	.
292	292	3	2	1	1	2	0.53	37	343	12.8	4.78	101	.
293	293	3	2	1	1	2	0.43	33	477	13.1	3.08	125	.
294	294	3	2	1	1	2	0.46	30	413	9.5	2.34	105	.
295	295	3	2	1	1	2	0.41	27	978	9.4	4.35	94	.
296	296	3	2	1	1	2	0.43	25	666	11.7	5.69	90	.
297	297	3	2	1	1	2	.	.	.	.	.	.	3.21
298	298	3	2	1	1	2	.	.	.	.	.	.	2.83
299	299	3	2	1	1	2	.	.	.	.	.	.	5.01
300	300	3	2	1	1	2	.	.	.	.	.	.	4.49
301	301	3	2	1	2	1	0.57	32	431	10.1	4.41	110	.
302	302	3	2	1	2	1	0.53	31	393	9.8	4.60	90	.
303	303	3	2	1	2	1	0.49	41	343	12.4	4.43	121	.
304	304	3	2	1	2	1	0.48	29	511	11.3	4.18	117	.
305	305	3	2	1	2	1	0.61	28	418	10.4	6.90	104	.
306	306	3	2	1	2	1	0.71	30	691	10.6	5.81	90	.
307	307	3	2	1	2	1	.	.	.	.	.	.	2.84
308	308	3	2	1	2	1	.	.	.	.	.	.	1.94
309	309	3	2	1	2	1	.	.	.	.	.	.	3.28
310	310	3	2	1	2	1	.	.	.	.	.	.	3.19
311	311	3	2	1	2	2	0.67	27	710	9.9	6.01	96	.
312	312	3	2	1	2	2	0.63	29	481	10.4	5.40	103	.
313	313	3	2	1	2	2	0.48	33	392	11.2	5.18	97	.
314	314	3	2	1	2	2	0.43	42	542	9.9	4.90	98	.

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                                                 LIVER DATA

OBS   SAMPLE   TYPE   SEASON   REGION   FARM   CLASS   L_CO   L_CU   L_FE   L_MN   L_MO   L_ZN   L_SE

315    315      3       2        1        2      2     0.47    29     542    9.4   4.61     97      .
316    316      3       2        1        2      2     0.49    35     481   12.4   5.03    101      .
317    317      3       2        1        2      2      .       .       .      .      .       .    2.80
318    318      3       2        1        2      2      .       .       .      .      .       .    3.41
319    319      3       2        1        2      2      .       .       .      .      .       .    2.39
320    320      3       2        1        2      2      .       .       .      .      .       .    3.28
321    321      3       2        1        3      1     0.33    24     714   11.1   2.57    106      .
322    322      3       2        1        3      1     0.48    22     538   15.3   3.63    120      .
323    323      3       2        1        3      1     0.57    24     505   12.3   3.45     95      .
324    324      3       2        1        3      1     0.71    30     384   13.9   4.18     86      .
325    325      3       2        1        3      1     0.67    32     778   11.3   3.41    135      .
326    326      3       2        1        3      1     0.69    29     905   12.3   4.26    116      .
327    327      3       2        1        3      1      .       .       .      .      .       .    3.46
328    328      3       2        1        3      1      .       .       .      .      .       .    2.72
329    329      3       2        1        3      1      .       .       .      .      .       .    3.57
330    330      3       2        1        3      1      .       .       .      .      .       .    2.21
331    331      3       2        1        3      2     0.69    24     548   15.0   6.90    121      .
332    332      3       2        1        3      2     0.49    34     341   15.3   4.36    103      .
333    333      3       2        1        3      2     0.68    46     496   11.0   3.04    104      .
334    334      3       2        1        3      2     0.57    36     473   13.0   2.01     91      .
335    335      3       2        1        3      2     0.56    24     994   11.8   7.39     95      .
336    336      3       2        1        3      2     0.53    29     387   15.2   4.88     98      .
337    337      3       2        1        3      2      .       .       .      .      .       .    3.40
338    338      3       2        1        3      2      .       .       .      .      .       .    3.10
339    339      3       2        1        3      2      .       .       .      .      .       .    2.90
340    340      3       2        1        3      2      .       .       .      .      .       .    2.41
341    341      3       2        1        4      1     0.53    23     405   15.8   3.11     85      .
342    342      3       2        1        4      1     0.58    28     436   16.0   3.47    105      .
343    343      3       2        1        4      1     0.58    20     582   16.1   4.22     90      .
344    344      3       2        1        4      1     0.69    15     427   19.1   3.17    102      .
345    345      3       2        1        4      1     0.90    18     463   16.6   2.51    109      .
346    346      3       2        1        4      1     0.93    88     450   16.0   4.63     99      .
347    347      3       2        1        4      1      .       .       .      .      .       .    1.42
348    348      3       2        1        4      1      .       .       .      .      .       .    1.36
349    349      3       2        1        4      1      .       .       .      .      .       .    1.68
350    350      3       2        1        4      1      .       .       .      .      .       .    1.51
351    351      3       2        1        4      2     0.83    30     511   18.9   4.40     86      .
352    352      3       2        1        4      2     0.71    23     441   15.3   3.77     83      .
353    353      3       2        1        4      2     0.77    18     544   16.1   3.47     90      .
354    354      3       2        1        4      2     0.68    42     562   17.2   4.53     87      .
355    355      3       2        1        4      2     0.71    18     496   14.8   3.02    109      .
356    356      3       2        1        4      2     0.69    99     514   17.6   5.31     93      .
357    357      3       2        1        4      2      .       .       .      .      .       .    1.39
358    358      3       2        1        4      2      .       .       .      .      .       .    1.74
359    359      3       2        1        4      2      .       .       .      .      .       .    1.41
360    360      3       2        1        4      2      .       .       .      .      .       .    1.97
361    361      3       2        2        5      1     0.49    32     441    2.4   2.67     97      .
362    362      3       2        2        5      1     0.58    74     474    2.6   3.51    157      .
363    363      3       2        2        5      1     0.53    28     297    8.9   3.44    121      .
364    364      3       2        2        5      1     0.55    98     449    5.3   3.42    147      .
365    365      3       2        2        5      1     0.53    16     384    8.7   3.38     93      .
366    366      3       2        2        5      1     0.81    52     576    6.2   3.31    104      .
367    367      3       2        2        5      1      .       .       .      .      .       .    0.22
368    368      3       2        2        5      1      .       .       .      .      .       .    0.63
369    369      3       2        2        5      1      .       .       .      .      .       .    0.23
370    370      3       2        2        5      1      .       .       .      .      .       .    0.52

371    371      3       2        2        5      2     C.56    31     448    9.4   2.97    104      .
372    372      3       2        2        5      2     0.34    29     468    9.7   2.74    155      .
373    373      3       2        2        5      2     0.53    45     351    5.6   3.28    119      .
374    374      3       2        2        5      2     0.61    22     495    8.6   3.36    164      .
375    375      3       2        2        5      2     0.81    46     606    6.4   3.29    107      .
376    376      3       2        2        5      2     0.50    49     468    3.7   3.95    113      .
377    377      3       2        2        5      2      .       .       .      .      .       .    0.29
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LIVER DATA

OBS	SAMPLE	TYPE	SEASON	REGION	FARM	CLASS	L_CO	L_CU	L_FE	L_MN	L_MO	L_ZN	L_SE
378	378	3	2	2	5	2	.	.	.	.	.	.	0.48
379	379	3	2	2	5	2	.	.	.	.	.	.	0.38
380	380	3	2	2	5	2	.	.	.	.	.	.	0.43
381	381	3	2	2	6	1	0.49	32	255	6.3	2.71	90	.
382	382	3	2	2	6	1	0.53	50	260	9.0	3.40	107	.
383	383	3	2	2	6	1	0.58	31	242	6.5	3.53	84	.
384	384	3	2	2	6	1	0.56	58	316	8.0	3.40	92	.
385	385	3	2	2	6	1	0.39	47	388	9.8	3.39	105	.
386	386	3	2	2	6	1	0.48	49	244	8.2	3.43	110	.
387	387	3	2	2	6	1	.	.	.	.	.	.	0.50
388	388	3	2	2	6	1	.	.	.	.	.	.	0.62
389	389	3	2	2	6	1	.	.	.	.	.	.	0.55
390	390	3	2	2	6	1	.	.	.	.	.	.	0.55
391	391	3	2	2	6	2	0.54	23	205	9.8	3.01	104	.
392	392	3	2	2	6	2	0.49	91	214	9.7	2.97	104	.
393	393	3	2	2	6	2	0.47	24	184	8.6	3.31	119	.
394	394	3	2	2	6	2	0.48	44	214	10.1	3.33	87	.
395	395	3	2	2	6	2	0.43	50	221	8.2	3.37	83	.
396	396	3	2	2	6	2	0.41	72	228	7.3	3.81	121	.
397	397	3	2	2	6	2	.	.	.	.	.	.	0.49
398	398	3	2	2	6	2	.	.	.	.	.	.	0.47
399	399	3	2	2	6	2	.	.	.	.	.	.	0.63
400	400	3	2	2	6	2	.	.	.	.	.	.	0.51
401	401	3	2	2	7	1	0.56	302	569	7.8	3.49	219	.
402	402	3	2	2	7	1	0.58	264	339	9.6	3.04	147	.
403	403	3	2	2	7	1	0.68	367	408	9.0	3.12	136	.
404	404	3	2	2	7	1	0.86	344	446	9.4	2.14	172	.
405	405	3	2	2	7	1	0.60	121	991	8.3	2.66	135	.
406	406	3	2	2	7	1	0.53	258	465	9.8	3.56	124	.
407	407	3	2	2	7	1	.	.	.	.	.	.	0.73
408	408	3	2	2	7	1	.	.	.	.	.	.	1.22
409	409	3	2	2	7	1	.	.	.	.	.	.	1.05
410	410	3	2	2	7	1	.	.	.	.	.	.	0.30
411	411	3	2	2	7	2	0.54	291	393	6.6	3.57	140	.
412	412	3	2	2	7	2	0.49	240	425	7.3	3.72	156	.
413	413	3	2	2	7	2	0.63	209	485	4.7	2.34	123	.
414	414	3	2	2	7	2	0.62	224	425	8.4	2.87	131	.
415	415	3	2	2	7	2	0.53	175	321	5.8	2.39	113	.
416	416	3	2	2	7	2	0.57	71	164	4.9	2.06	45	.
417	417	3	2	2	7	2	.	.	.	.	.	.	0.69
418	418	3	2	2	7	2	.	.	.	.	.	.	1.31
419	419	3	2	2	7	2	.	.	.	.	.	.	1.11
420	420	3	2	2	7	2	.	.	.	.	.	.	1.19
421	421	3	2	2	8	1	0.49	112	156	5.4	3.38	92	.
422	422	3	2	2	8	1	0.38	263	320	5.7	3.60	131	.
423	423	3	2	2	8	1	0.43	131	228	10.8	2.98	66	.
424	424	3	2	2	8	1	0.41	141	233	9.2	3.57	99	.
425	425	3	2	2	8	1	0.53	120	352	8.2	3.40	117	.
426	426	3	2	2	8	1	0.49	121	356	11.0	3.11	90	.
427	427	3	2	2	8	1	.	.	.	.	.	.	0.51
428	428	3	2	2	8	1	.	.	.	.	.	.	0.67
429	429	3	2	2	8	1	.	.	.	.	.	.	0.48
430	430	3	2	2	8	1	.	.	.	.	.	.	0.59
431	431	3	2	2	8	2	0.47	131	252	8.8	2.31	103	.
432	432	3	2	2	8	2	0.58	128	226	7.7	2.44	89	.
433	433	3	2	2	8	2	0.33	129	309	7.0	2.48	77	.
434	434	3	2	2	8	2	0.39	90	305	9.5	3.01	102	.
435	435	3	2	2	8	2	0.43	160	271	9.5	2.69	107	.
436	436	3	2	2	8	2	0.44	150	327	7.9	2.23	101	.
437	437	3	2	2	8	2	.	.	.	.	.	.	0.61
438	438	3	2	2	8	2	.	.	.	.	.	.	0.71
439	439	3	2	2	8	2	.	.	.	.	.	.	0.89
440	440	3	2	2	8	2	.	.	.	.	.	.	1.15
441	441	3	2	3	9	1	0.66	344	689	8.9	3.34	116	.

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                                                      LIVER DATA

 OBS   SAMPLE   TYPE   SEASON   REGION   FARM   CLASS   L_CO   L_CU   L_FE   L_MN   L_MO   L_ZN   L_SE

 442    442      3       2        3        9      1     0.59    413    452    7.2   2.77    108     .
 443    443      3       2        3        9      1     0.65    445    250    9.2   1.95    118     .
 444    444      3       2        3        9      1     0.69    117    811    3.6   3.00    149     .

 445    445      3       2        3        9      1     0.60    107    755    8.0   3.71    156     .
 446    446      3       2        3        9      1     0.59    482    491    6.9   3.02    126     .
 447    447      3       2        3        9      1      .       .      .      .      .       .    0.32
 448    448      3       2        3        9      1      .       .      .      .      .       .    0.44
 449    449      3       2        3        9      1      .       .      .      .      .       .    0.39
 450    450      3       2        3        9      1      .       .      .      .      .       .    0.31
 451    451      3       2        3        9      2     0.60    312    394    4.6   3.30    128     .
 452    452      3       2        3        9      2     0.63    439    425   12.9   3.87    103     .
 453    453      3       2        3        9      2     0.58    175    353    6.3   1.15    119     .
 454    454      3       2        3        9      2     0.59    227    512   10.2   2.86     96     .
 455    455      3       2        3        9      2     0.60    305    407    5.6   4.26    127     .
 456    456      3       2        3        9      2     0.67    337    406   10.1   2.30    101     .
 457    457      3       2        3        9      2      .       .      .      .      .       .    0.37
 458    458      3       2        3        9      2      .       .      .      .      .       .    0.39
 459    459      3       2        3        9      2      .       .      .      .      .       .    0.41
 460    460      3       2        3        9      2      .       .      .      .      .       .    0.35
 461    461      3       2        3       10      1     0.50     83    280    6.0   2.69     95     .
 462    462      3       2        3       10      1     0.41     94    277    9.8   2.83    109     .
 463    463      3       2        3       10      1     0.80    183    584   11.3   3.14     84     .
 464    464      3       2        3       10      1     0.51     93    291    5.7   2.56    101     .
 465    465      3       2        3       10      1     0.55    300    399    6.9   5.59    123     .
 466    466      3       2        3       10      1     0.77    131    330   10.1   2.84     77     .
 467    467      3       2        3       10      1      .       .      .      .      .       .    0.07
 468    468      3       2        3       10      1      .       .      .      .      .       .    0.15
 469    469      3       2        3       10      1      .       .      .      .      .       .    0.08
 470    470      3       2        3       10      1      .       .      .      .      .       .    0.03
 471    471      3       2        3       10      2     0.41    264    487   11.6   3.05    103     .
 472    472      3       2        3       10      2     0.56     78    370    9.0   3.11     95     .
 473    473      3       2        3       10      2     0.71    142    399    5.5   2.96     91     .
 474    474      3       2        3       10      2     0.42    143    343    6.6   3.53    115     .
 475    475      3       2        3       10      2     0.60    156    605    3.2   3.72    151     .
 476    476      3       2        3       10      2     0.90    320    336    9.0   2.73    132     .
 477    477      3       2        3       10      2      .       .      .      .      .       .    0.12
 478    478      3       2        3       10      2      .       .      .      .      .       .    0.14
 479    479      3       2        3       10      2      .       .      .      .      .       .    0.21
 480    480      3       2        3       10      2      .       .      .      .      .       .    0.17
 481    481      3       2        3       11      1     0.97    276    764   11.4   4.34    118     .
 482    482      3       2        3       11      1     0.90    326    406   11.4   4.33    131     .
 483    483      3       2        3       11      1     0.58    263    291    7.5   2.69    109     .
 484    484      3       2        3       11      1     1.17    300    626    8.6   3.24    105     .
 485    485      3       2        3       11      1     0.99    327    779   15.6   3.29    123     .
 486    486      3       2        3       11      1     0.93    241    840   13.4   3.52     91     .
 487    487      3       2        3       11      1      .       .      .      .      .       .    1.24
 488    488      3       2        3       11      1      .       .      .      .      .       .    0.74
 489    489      3       2        3       11      1      .       .      .      .      .       .    0.71
 490    490      3       2        3       11      1      .       .      .      .      .       .    0.73
 491    491      3       2        3       11      2     0.90    220    510    8.2   3.50    110     .
 492    492      3       2        3       11      2     1.11    316    570   14.3   3.96    144     .
 493    493      3       2        3       11      2     0.85    318    694    6.0   3.53    131     .
 494    494      3       2        3       11      2     0.83    230    481    9.3   3.29    107     .
 495    495      3       2        3       11      2     0.87    245    493    9.6   3.58    120     .
 496    496      3       2        3       11      2     0.81    260    281   10.2   3.30    130     .
 497    497      3       2        3       11      2      .       .      .      .      .       .    0.69
 498    498      3       2        3       11      2      .       .      .      .      .       .    0.77
 499    499      3       2        3       11      2      .       .      .      .      .       .    0.81
 500    500      3       2        3       11      2      .       .      .      .      .       .    0.76
 501    501      3       2        3       12      1     0.90    280    692   11.0   3.05    132     .
 502    502      3       2        3       12      1     0.68    109    499    6.4   1.25    134     .
 503    503      3       2        3       12      1     0.45    365    552    9.2   2.63    126     .
 504    504      3       2        3       12      1     0.57    324    504   10.3   3.20    138     .
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                                             LIVER DATA
OBS  SAMPLE  TYPE  SEASON  REGION  FARM  CLASS  L_CO  L_CU  L_FE  L_MN  L_MO  L_ZN  L_SE

505   505     3      2       3      12     1    0.41   457   525  13.1  2.13   141    .
506   506     3      2       3      12     1    0.98   399   587   7.7  2.38   146    .
507   507     3      2       3      12     1     .      .     .     .     .      .   0.71
508   508     3      2       3      12     1     .      .     .     .     .      .   0.66
509   509     3      2       3      12     1     .      .     .     .     .      .   0.62
510   510     3      2       3      12     1     .      .     .     .     .      .   0.60
511   511     3      2       3      12     2    0.86   244   445   7.4  1.65    96    .
512   512     3      2       3      12     2    0.49   104   547  11.9  3.67   183    .
513   513     3      2       3      12     2    0.42   256   606   6.9  3.37   116    .
514   514     3      2       3      12     2    0.87   213   329   6.6  3.09    91    .
515   515     3      2       3      12     2    0.50    64   567  10.4  3.58   196    .
516   516     3      2       3      12     2    0.90   113   307   5.8  2.13   161    .
517   517     3      2       3      12     2     .      .     .     .     .      .   0.68
518   518     3      2       3      12     2     .      .     .     .     .      .   0.65

519   519     3      2       3      12     2     .      .     .     .     .      .   0.71
520   520     3      2       3      12     2     .      .     .     .     .      .   0.63
521   521     3      2       3      13     1    0.98   468   338   7.0  3.42   105    .
522   522     3      2       3      13     1    0.93   203   276   4.8  3.28   174    .
523   523     3      2       3      13     1    0.67   309   472   4.8  3.40   137    .
524   524     3      2       3      13     1    0.54   226   363   7.8  4.31    99    .
525   525     3      2       3      13     1    0.62   127   365   8.4  2.28   151    .
526   526     3      2       3      13     1    0.83   206   453   2.6  3.86   101    .
527   527     3      2       3      13     1     .      .     .     .     .      .   0.42
528   528     3      2       3      13     1     .      .     .     .     .      .   0.38
529   529     3      2       3      13     1     .      .     .     .     .      .   0.34
530   530     3      2       3      13     1     .      .     .     .     .      .   0.65
531   531     3      2       3      13     2    0.90   462   349   7.6  2.64   100    .
532   532     3      2       3      13     2    0.60   190   260   9.8  2.73   160    .
533   533     3      2       3      13     2    0.67   290   517  11.6  3.23   120    .
534   534     3      2       3      13     2    0.64   247   405  12.3  2.83    97    .
535   535     3      2       3      13     2    0.48   133   371  11.8  2.29   151    .
536   536     3      2       3      13     2    0.46   193   348   9.4  3.64    99    .
537   537     3      2       3      13     2     .      .     .     .     .      .   0.29
538   538     3      2       3      13     2     .      .     .     .     .      .   0.43
539   539     3      2       3      13     2     .      .     .     .     .      .   0.37
540   540     3      2       3      13     2     .      .     .     .     .      .   0.35
541   541     3      2       3      14     1    0.52    21   280   6.2  2.59    99    .
542   542     3      2       3      14     1    0.41    23   500   8.5  5.60   112    .
543   543     3      2       3      14     1    0.44    27   208   5.3  4.14    90    .
544   544     3      2       3      14     1    0.63    37   537   4.7  4.02   107    .
545   545     3      2       3      14     1    0.34    64   490   2.7  4.23    91    .
546   546     3      2       3      14     1    0.40    20   314   4.5  2.80    84    .
547   547     3      2       3      14     1     .      .     .     .     .      .   1.48
548   548     3      2       3      14     1     .      .     .     .     .      .   0.67
549   549     3      2       3      14     1     .      .     .     .     .      .   2.14
550   550     3      2       3      14     1     .      .     .     .     .      .   1.08
551   551     3      2       3      14     2    0.41    16   277   5.9  4.86    95    .
552   552     3      2       3      14     2    0.32    23   429   8.2  3.64    97    .
553   553     3      2       3      14     2    0.37    29   253   5.2  4.29    91    .
554   554     3      2       3      14     2    0.53    43   487   3.6  3.21   112    .
555   555     3      2       3      14     2    0.50    80   536   4.8  5.43   100    .
556   556     3      2       3      14     2    0.54    33   355   5.9  4.04    98    .
557   557     3      2       3      14     2     .      .     .     .     .      .   1.29
558   558     3      2       3      14     2     .      .     .     .     .      .   1.40
559   559     3      2       3      14     2     .      .     .     .     .      .   1.81
560   560     3      2       3      14     2     .      .     .     .     .      .   0.91
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BIOGRAPHICAL SKETCH

Rodrigo Tejada was born in Guatemala on January 10, 1955, the son of Dr. Carlos Tejada and Isabel Castillo de Tejada. He attended the American School of Guatemala from which he graduated in 1972. The following year, he enrolled in the University of San Carlos of Guatemala and graduated with a Bachelor's degree in Animal Science in July, 1979. The author was an Assistant Professor of Animal Nutrition at the same school previous to graduation.

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He is currently a member of the American Society of Animal Science, the American Society of Dairy Science and a member of the Honor Society of Agriculture, Gamma Sigma Delta.

He is married to the former Kimberly Ann Castillo and has a daughter, Analee.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Lee R. McDowell

Lee R. McDowell, Chairman
Professor of Animal Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Joseph H Conrad

Joseph H. Conrad
Professor of Animal Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Frank G. Martin
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